A CAHNERS PUBLICATION INTERNATIONAL EDITION JUNE 9, 1988

EDN®

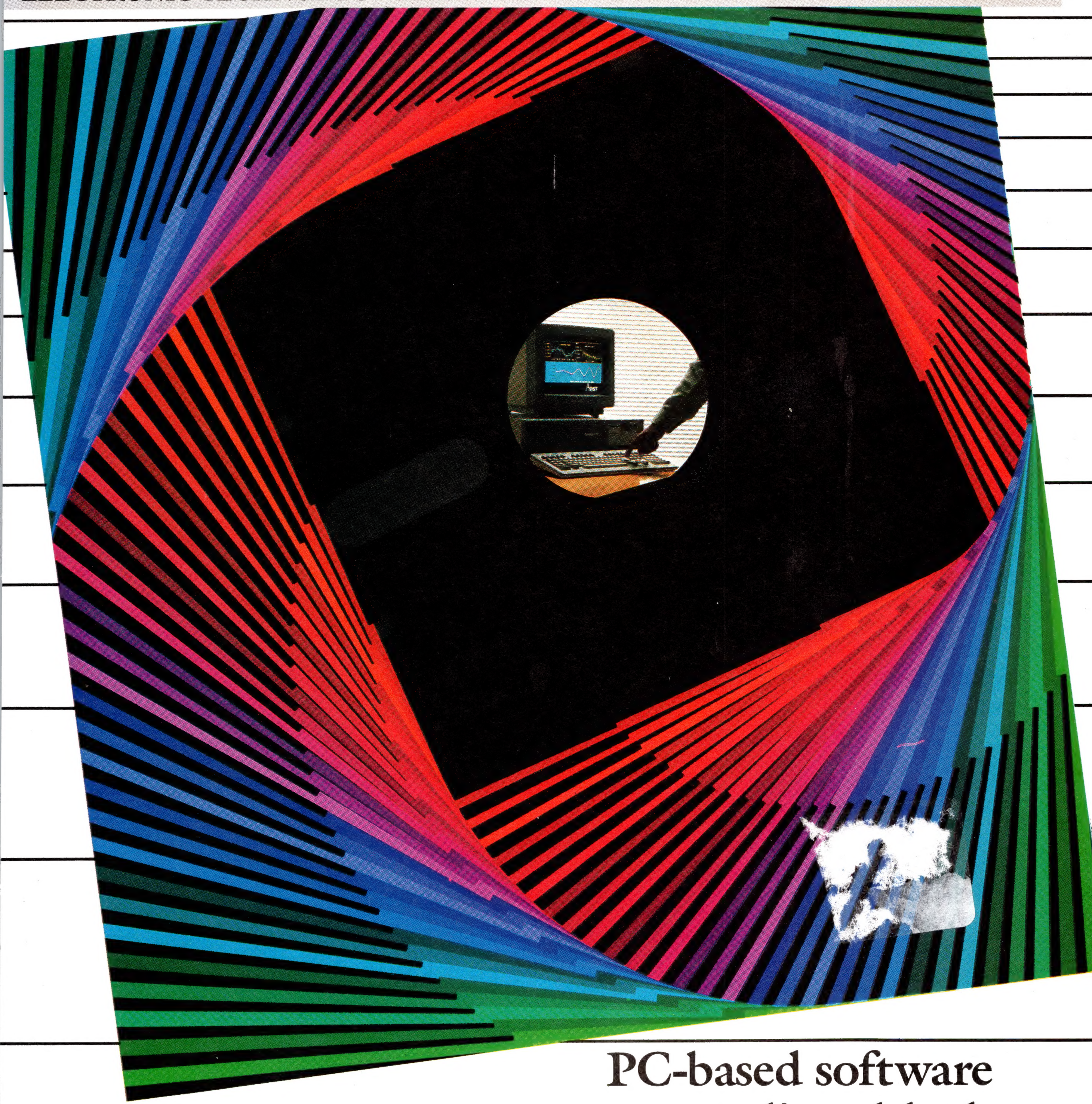
EDN's 11th annual μP support-chip directory

Designer's Guide to state machines—Part 2

GaAs ICs suit complex VLSI designs

Fiber-optic ICs

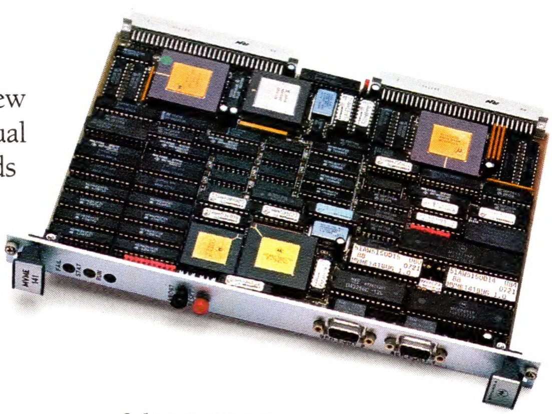
ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



PC-based software automates tedious lab chores

MVME141 HIGH PERFORMANCE CPU

"The 030 running at up to 8 MIPS makes Motorola's new VME board the fastest on the market."



OEMs are finding our new MVME141 module resets the usual performance limits for CPU boards at the high end. Because it handles demanding applications like engineering simulation, computer animation and image processing at blazing speeds.

For openers, the 141 boasts a powerful MC68030 MPU and floating-point coprocessor, both running at up to 30 MHz. Then, to enhance memory and peripheral access speeds, the 141 adds three new ASICs—the VMEbus interface chip, the VME subsystem bus (VSB) chip and a custom cache controller gate array.

What really boosts computing horsepower, though, is the 141's direct-mapped 6.4 Kbyte cache, which features a hit rate of greater than 90%. Implemented with 15-nsec Motorola SRAM technology, with write-posting interface, the cache allows continuous 2-cycle read access, letting the 030 operate at its maximum potential.

A companion 4/8 Mbyte memory board, the MVME224-2, has been fine tuned to work with the 141 CPU module. It features dual-ported VMEbus and VSB interfaces, and a patented arbitration circuit that minimizes memory access times.

To move your UNIX® and real-time applications up to the new high-performance standard in VME boards, call us today—toll free: **1-800-556-1234, Ext. 230;** in California, 1-800-441-2345, Ext. 230. Or write: Motorola Microcomputer Division, 2900 Diablo Way, Tempe, AZ 85282.

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MOTOROLA *Microcomputer Division*

Approaching our technology from your point of view.

CIRCLE NO 91

WHY VTC? ASK THE VME CONSORTIUM.

"For a bunch of companies that don't always agree on everything, we sure were unanimous on VTC."

Joseph Ramunni, chairman (left), and Jack Regula, technical director, VME Technology Consortium.

The VME Consortium needed an economical, yet highly functional VME bus interface chip, to minimize design time . . . and to help raise the VME standard to higher levels.

"We looked at the leading suppliers," said Joe Ramunni, consortium chairman (and president of Mizar), "and VTC came out on top. Their CMOS standard-cell ASIC approach gave us the high drive capability we needed, optimized for bus interfacing. And, it proved much more cost-effective, with higher performance, than gate array technology."

The VME Consortium is made up of such firms as Plessey Microsystems, Omnibyte Corporation, Mizar Inc., Ironics Inc., Heurikon Corporation, Matrix Corporation, and Clearpoint Inc., among others. What did they look for in a supplier?

"We needed a credible business partner," said Ramunni, "with a proven track record, who could provide a turnkey package . . . both design and fab. A supplier that could produce in quantity, and provide technical support to the market at large.

"We also needed a firm with an international marketing structure, because we expect this chip to be the de facto standard worldwide.

"But, we needed *people* we could work with, too. VTC had the right 'comfort factor'."

Jack Regula, consortium technical director (and VP-R&D, Ironics) added: "Our requirements for high speed, high gate-count, low power consumption, and VME bus drive capability were all met well with VTC's 1-micron CMOS standard cell library. And we were extremely impressed with VTC's facilities, its people, and its customer list."

In the future, the VME bus chip (VIC) will become a standard cell within VTC's CMOS library, to allow customers to further customize the chip.

Shouldn't you be getting to know VTC, too? You'll be in good company when you do. Call or write us today, and we'll send you our short-form product catalog, which describes our product offerings in linear signal processing, high-speed CMOS logic, mass storage ICs, bipolar ASIC, and CMOS ASIC.

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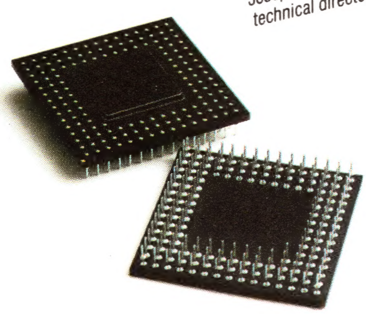

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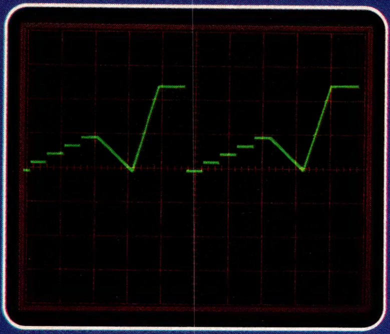
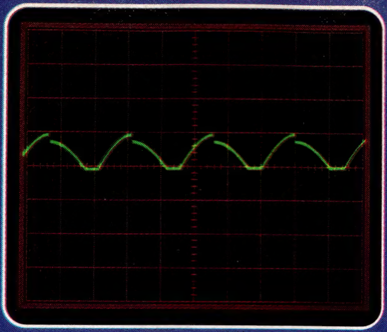
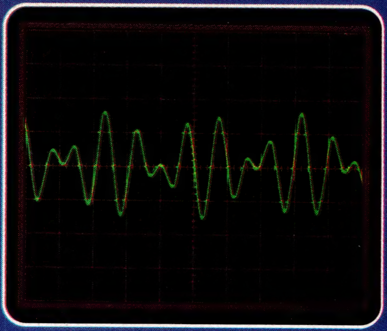


Vibration analysis with stop and hold.

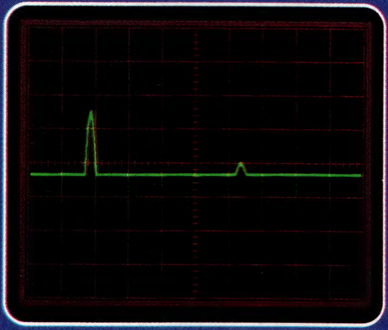


Complex waveforms for servo drives.

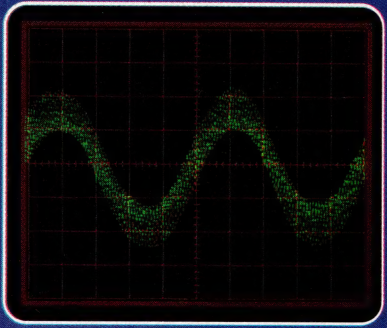


Dual tones for telephone testing.

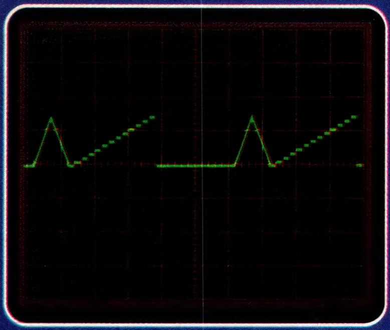
EKG and hemodynamic waveforms.



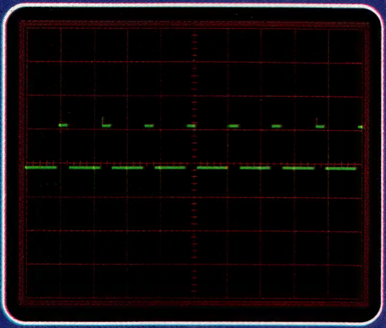
Radar/sonar envelope simulation.



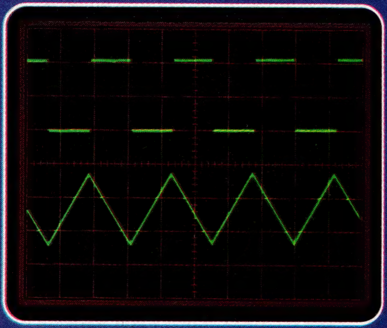
Noise added to any waveform.



A/D, amplifier development and calibration.



Digital testing and troubleshooting.



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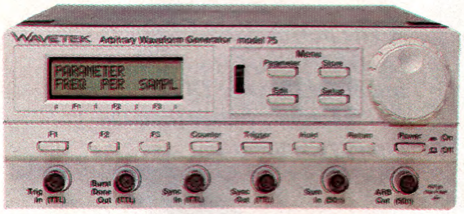
A quarter-century ago, Wavetek brought you the first waveforms produced by a solid-state function generator. Now our Model 75 Arbitrary Waveform/ Function Generator puts you in control.

Model 75 lets you generate waveforms without entering x/y coordinates. Thumbtack and rubberband modes allow easy development and editing of any waveform. There are also nine standard functions which you can use at the push of a button.



Waveforms are stored in nonvolatile memory, with more than 4,000 vertical points and 8,000 horizontal points of resolution. They can be played back at any rate, up to 500ns per point.

By linking two or more Model 75's together, you can superimpose waveforms to introduce phase displacement or other special effects. And at the low price, you might want to buy several.

For literature or to arrange an amazing demonstration, call or write Wavetek San Diego, Inc., P.O. Box 85265, San Diego, CA 92138. Phone (619) 279-2200; TWX (910) 335-2007.

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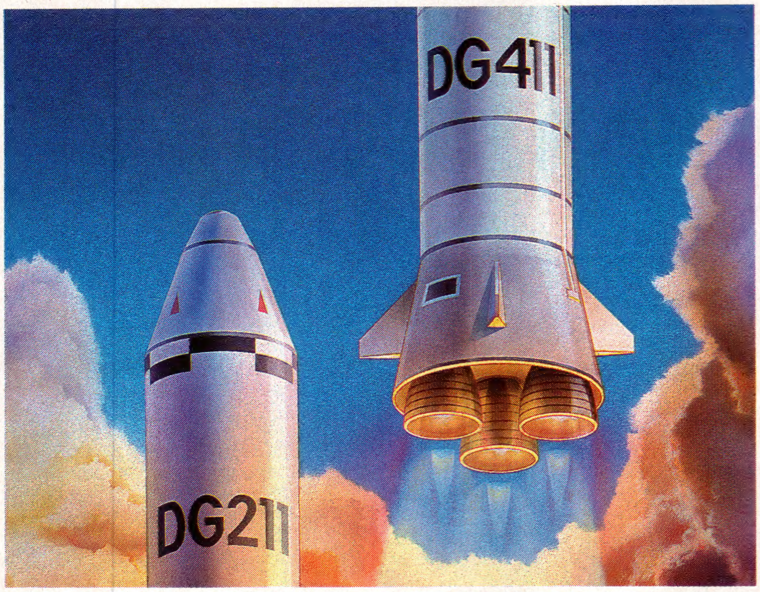
WAVETEK

330,000 X Performance Booster



Switch to the next generation with Siliconix' new silicon-gate DG400 family of analog switches.

Boost performance with lower ON-resistance, less leakage current and faster switching!

The next generation DG411/12/13 series of CMOS quad analog switches combine high performance, precision and low power. Previous technologies have forced the trade-offs of speed for low power, or ON-resistance for leakage. But the DG400 family lets you maximize all these parameters.

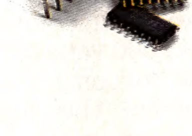
Next generation performance is only the beginning. Siliconix' new 44 V silicon-gate CMOS technology is more rugged! 2500 V (min.) ESP (Electro Static Discharge Protection) meets category B of MIL-STD 883B, method 3015.2 for your toughest reliability needs.

Quad Analog Switch Performance Comparison

DG211		DG411
1000 ns	Switching Speed	175 ns
20.4 mW	Power Dissipation	35 μW
5 nA	Leakage	250 pA
175 Ω	On Resistance	35 Ω
1	**Normalized Performance Product**	330,000

The DG411 family is optimized for minimum charge injection and for TTL-compatibility: Either unipolar 12 V supply or split supply operation.

◀ *The performance product, $r_{DS(ON)} \times I_{S(ON)} \times t_{ON} \times PD$, indicates that the DG411 is 330,000 times better than the industry standard DG211.*



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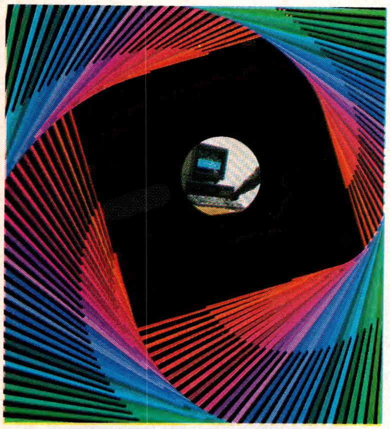
Volume 33, Number 12

EDN

June 9, 1988

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



***On the cover:** Personal-computer-based software greatly enhances an engineer's ability to create automated test systems. See pg 114. (Photo courtesy Asyst Software Technologies Inc)*

DESIGN FEATURES

Continued on page 7

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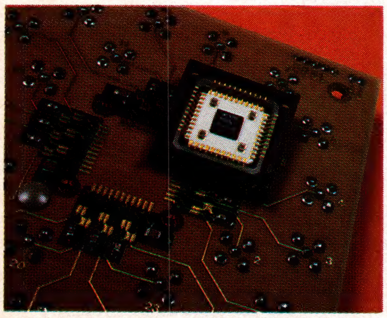

***Fiber-optic ICs** are becoming available in GaAs and are operating well into the gigahertz range (pg 63).*

TECHNOLOGY UPDATE

PRODUCT UPDATE

DESIGN IDEAS

Continued on page 9

EDN magazine now offers Express Request, a convenient way to retrieve product information by phone. See the Reader Service Card in the front for details on how to use this free service.

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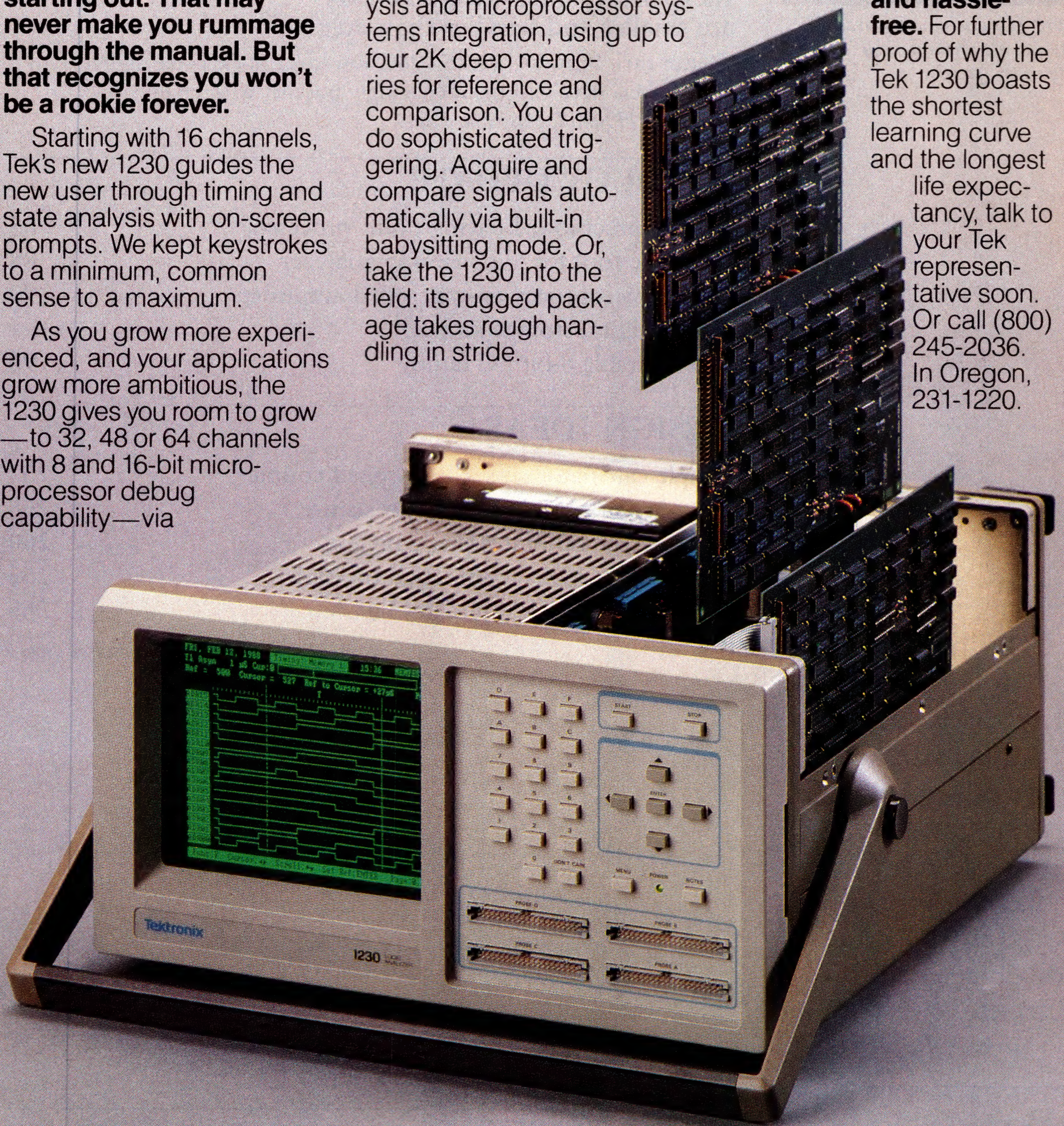
Now, you can have a logic analyzer that makes things simple when you're just starting out. That may never make you rummage through the manual. But that recognizes you won't be a rookie forever.

Starting with 16 channels, Tek's new 1230 guides the new user through timing and state analysis with on-screen prompts. We kept keystrokes to a minimum, common sense to a maximum.

As you grow more experienced, and your applications grow more ambitious, the 1230 gives you room to grow —to 32, 48 or 64 channels with 8 and 16-bit microprocessor debug capability—via expansion cards and probes you can easily add yourself.

You can do hardware analysis and microprocessor systems integration, using up to four 2K deep memories for reference and comparison. You can do sophisticated triggering. Acquire and compare signals automatically via built-in babysitting mode. Or, take the 1230 into the field: its rugged package takes rough handling in stride.

No other logic analyzer is so affordable, expandable and hassle-free. For further proof of why the Tek 1230 boasts the shortest learning curve and the longest life expectancy, talk to your Tek representative soon. Or call (800) 245-2036. In Oregon, 231-1220.



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Tektronix®
COMMITTED TO EXCELLENCE

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EDITORIAL 55

Watch out for people who tell you "it's easy," because it probably isn't.

NEW PRODUCTS

PROFESSIONAL ISSUES 342

What do college kids know: Students name their top employer choices.—*Deborah Asbrand, Associate Editor*

LOOKING AHEAD 353

Wider opportunities seen in European F-O market. . .Switching power supplies will grow at 14% annual rate.

DEPARTMENTS

A 386 µP.
155 supporting chips.
And no time
to breadboard.
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Mentor Graphics lets you simulate an 80386-based motherboard in only 4.3 minutes.

You're designing a complete 32-bit PC motherboard. And you're running out of time.

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Systems simulation requires a wide range of modeling technologies. And that's precisely what we deliver. Like Behavioral Language Models (BLMs), which transcend basic functionality and deliver features such as automatic error detection and reporting. And QuickParts,™ which combine maximum speed with minimum memory requirements—and produce timing behavior identical to the data book.

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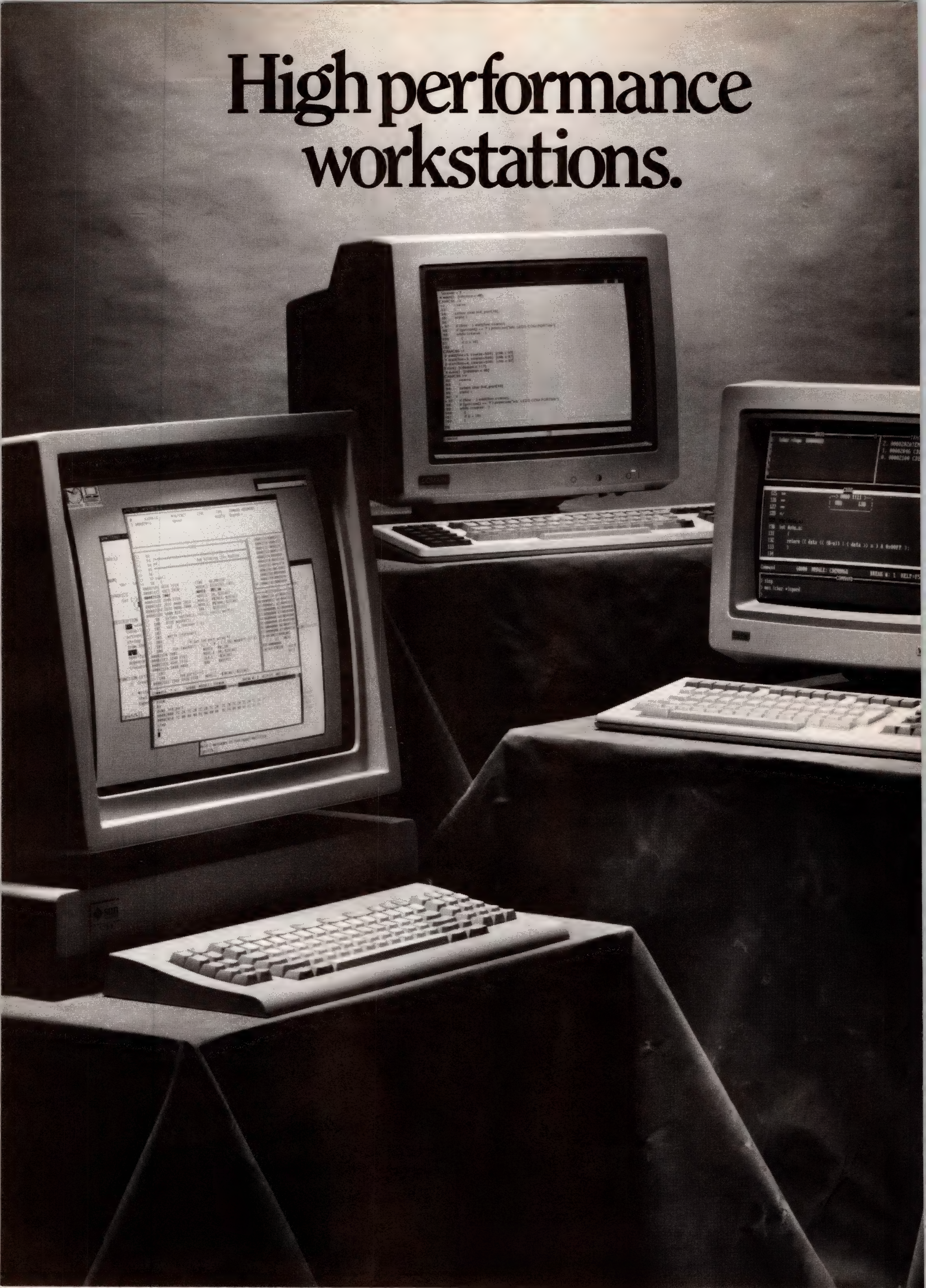
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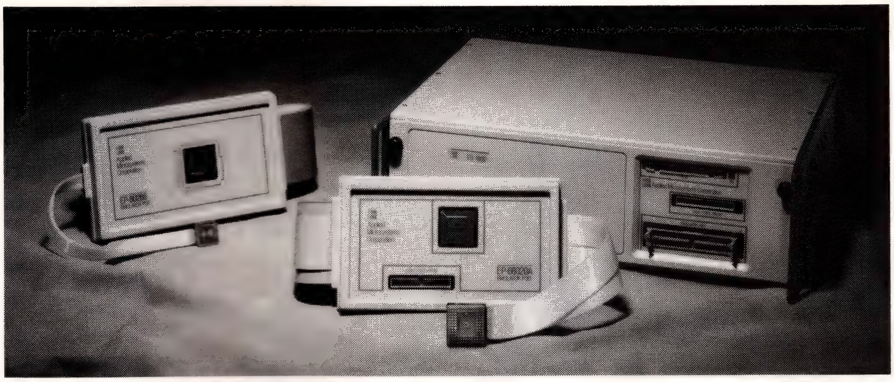

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Applied Microsystems Corporation


"Listen, the future of this product line is riding on my next design automation decision. Not to mention my job."
"I hear you. So tell me more and let's figure out how HP can help you make some of those decisions."

we never stop asking

"What if..."

"Well, first, we're feeling enormous pressure to get products out faster. The key is designs that'll go through manufacturing the first time. If we're going to stay competitive, we've got to tackle the overall product development process—and it starts right here in design."

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"That's exactly what we need. A single data path from design right on through production and out the door. If we could somehow combine electronic design with microprocessor development and mechanical engineering and tie it into manufacturing and test, we'd be a lot happier. Are you saying HP can do that for us now?"

"We're not there 100% yet. Nobody is. But that's the whole idea behind our DesignCenter. Right now, we've got the broadest set of EDA tools there is. Match them up with the HP test and measurement tools you've used for years, and you'll be way ahead of the game."

"We've always counted on HP test equipment. But how does that relate to your EDA tools?"

"We were able to bridge the gap between design and prototype test. Now you can create higher quality tests—faster, too—by transferring data directly between our logic analyzers and simulation. And the design and layout tie directly into HP board test systems."

"That's terrific. But testing is only one part of the process. We're making decisions on everything from ASICs and PLDs to microwave hybrids to multi-layer PCBs. And they all have different parts and technologies. I'll tell you, it's impossible to keep up."

"We agree, it's a big problem. But that's the reason we have digital, analog, and microwave CAE tools for design, simulation, and layout. We even support it all with information management to handle the tough tradeoffs your team has to make in choosing between all the technologies and complex interactions."

"There's one thing that's always a concern. We've got systems in here from some of your competitors. If we go with HP, can you fit into our existing environment?"

"Absolutely. Using either off-the-shelf or customized interfaces, we'll help you integrate HP tools into your existing systems. And, since HP supports EDIF and IGES standards, you'll have the flexibility you need down the road."

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"I get the feeling you understand that we're interested in a lot more than just tools. I mean, you seem to be talking about more than hardware and software."

"I am. HP is totally committed to this idea of getting more correct-by-design products through your plant. We *are* talking about a lot more than the tools. We'll sit down with you and help create a system that meets your needs . . . not ours or somebody else's. And I mean we'll get right down to solving problems and training your people. That's what we do better than anyone else."

"I want to keep talking about this whole thing. And I want to include some other engineers, too. What are you doing next Wednesday?"

"I've got a feeling I'll be back here."

"Right."

"Name a time."

The dialogue continues . . .

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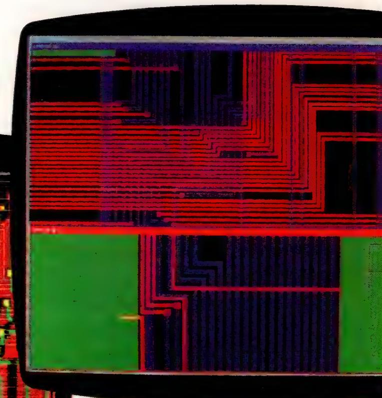

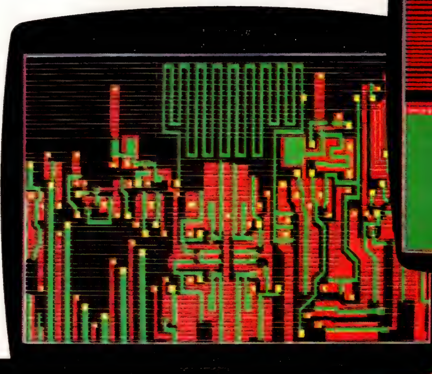

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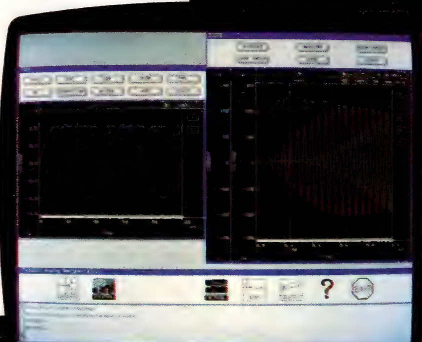

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CIRCLE NO 201

NEWS BREAKS

EDITED BY JOANNE CLAY

CONTENT-ADDRESSABLE DATA MANAGER SORTS 400 TIMES FASTER

By designing your board to use the Am95C85 Content-Addressable Data Manager (CADM) chip from Advanced Micro Devices (Austin, TX, (512) 462-4360) as the coprocessor, you can make the board sort and manipulate data 400 times faster than an IBM PC/XT and 50 times faster than a VAX 11/785 system. This 44-pin, 1.6-μm CMOS device can relieve your system's host CPU of time-consuming data-manipulation and -management tasks. Using parallel-processing techniques, the CADM can perform content-addressable searching of 3-byte fields in less than 10 μsec. You can also use this coprocessor to perform automatic sorting and address-independent record storage or deletion in software-configurable tables. Because the CADM combines the advantages of a content-addressable memory with the flexibility of a RAM, you don't have to provide physical addresses to access its memory. As a result, a single command lets the device manipulate and retrieve data at hardware speeds.

A stack mode lets you store data in the device without resorting it and permits you to delete records by simply popping them out of memory. This μP peripheral contains a 1k-byte software-configurable RAM array, a control unit that manages internal data, and a host-system interface. Sixteen commands constitute the chip's set of initialization-, byte-, and record-oriented instructions. You can cascade as many as 256 of these 16-MHz devices, which sell for $66.50 (100). A 12-MHz version costs $49.20 (100).—J D Mosley

TRACKBALL FREES YOUR PC's SERIAL PORT

You can replace your PC's mouse with a trackball—even if you don't have an extra serial port—by using the Model M6 Mouse-Trak cursor controller from Itac Systems (Garland, TX, (214) 494-3073). This bus-version trackball comes with a card that plugs into any IBM PC or compatible computer, and provides both a port for the trackball and an extra RS-232C port. Simply by flipping a switch, you can make the Mouse-Trak emulate either a Microsoft or a Mouse Systems mouse. Even if your existing software doesn't accommodate mouse-oriented cursor control, the Mouse-Trak's key-definition program lets the trackball emulate your PC's arrow keys and lets you assign as many as 127 keystrokes to each of its three ergonomically positioned buttons.

The Mouse-Trak draws its power from the RS-232C interface; it requires no additional power supply. For applications requiring precise cursor control, a speed-control button lets you toggle to ¼ speed. The trackball's Toggle mode lets you drag icons across the screen without holding down a button. The M6 sells for $189; other models are available for DEC, SUN, Apollo, Apple, and Atari computers.—J D Mosley

SMALL OPTICAL-DISK DRIVES EMPLOY ERASABLE MEDIA

The 5¼-in. Tahiti I and the 3½-in. Fiji I optical-disk drives from Maxtor Corp (San Jose, CA, (408) 432-1700) store 1G and 160M bytes, respectively, on erasable, magneto-optic media in removable cartridges. The Tahiti I accepts double-sided cartridges in the company's proprietary format, which holds 500M bytes per side, or an ANSI-standard cartridge, which holds 300M bytes per side and allows for data interchange with optical drives from other vendors. In addition, the Tahiti I features a 30-msec average seek time and an average data-transfer rate of 10M bps, so its performance is comparable to that of many magnetic, fixed hard-disk drives.

For applications that require a smaller, lower-capacity, lower-performance, and lower-cost peripheral, you can use the Fiji I, which stores 160M bytes on a single-sided

cartridge. It features a 100-msec average seek time and a 1.9M-bps data-transfer rate. Both drives employ the SCSI interface, but the Tahiti I includes a SCSI controller within its 5¼-in., full-height envelope, and the smaller Fiji I requires a separate controller board. The drives will be available in production quantities by September. In OEM quantities, the Tahiti I will cost approximately $2500 and the Fiji I will cost less than $1000.—Steven H Leibson

ERASABLE OPTICAL CD ANNOUNCED; APPLICATIONS PENDING

Tandy Corp (Fort Worth, TX, (817) 390-3700) recently announced that it has developed an erasable optical disk, the Thor-CD. The Thor-CD uses a laser beam to record, play back, store, and erase digital data on a disk that is compatible with all existing CD audio and CD-ROM players. The first system that can use the disk will be a $500 audio CD player/recorder. The company estimates the product will be commercially available in 1½ to 2 years. At least another year will pass before the company offers CD-ROM and video player/recorders that use the Thor-CD.—J D Mosley

32-BIT RISC MICROPROCESSOR IS NOW AVAILABLE IN QUANTITY

Three versions of the Am29000 RISC (reduced-instruction-set computer) microprocessor are now available in quantity from Advanced Micro Devices (Sunnyvale, CA, (408) 732-2400). The 11-, 14-, and 17-MIPS (million instructions per second) versions cost $174, $230, and $349 (100), respectively. (These MIPS ratings are specific to the Am29000 microprocessor and are not equivalent to VAX MIPS ratings.)—Doug Conner

MIL-SPEC BOARD SET PUTS 80386 ON MULTIBUS I

To implement 32-bit-wide processing capability on your Multibus I-based military application, you can use the 32 SECS 80 Engine from Titan/Sesco Corp (Chatsworth, CA, (818) 709-7100). This 3-board set achieves 32-bit performance on the 16-bit Multibus I by using the manufacturer's prorietary 32-bit-wide intermodule LocalBus for address and data. (The intermodule bus is similar to the Multibus II's, but it lacks multiple-master support.) The full-military-spec board set comprises an 80386-based processor module combined with either a dual-port EPROM/RAM module or a dual-port dynamic-RAM module, or both. All of the modules plug directly into the Multibus I backplane. The CPU module contains a 16-MHz version of the 80386 with optional 80387 support, a serial I/O channel, a 128k-byte EPROM, and 64k bytes of static RAM; the vendor claims the board set achieves a maximum performance rating of 650,000 Whetstones SP. The price for the 3-board set, with 4M bytes of RAM, is $30,000.
—Margery S Conner

SOFTWARE PACKAGE SUPPORTS EMBEDDED 8086 CODE DEVELOPMENT

The C-thru-ROM software package from Datalight (Bothell, WA, (206) 486-8086) allows you to use Microsoft's C compilers to develop ROM-based programs for μPs that execute 8086 code. Usually, these compilers create programs that require an IBM PC environment complete with support from MS DOS. However, the $495 C-thru-ROM package provides a locater, prewritten startup code, and step-by-step instructions for creating ROMable, stand-alone programs that require no operating system. The package also includes a remote debugger for your PC and a small software kernel that runs on your target system; the debugger and kernel allow you to debug code on your target through the PC's serial port.—Steven H Leibson

Flash A/D conversion as easy as

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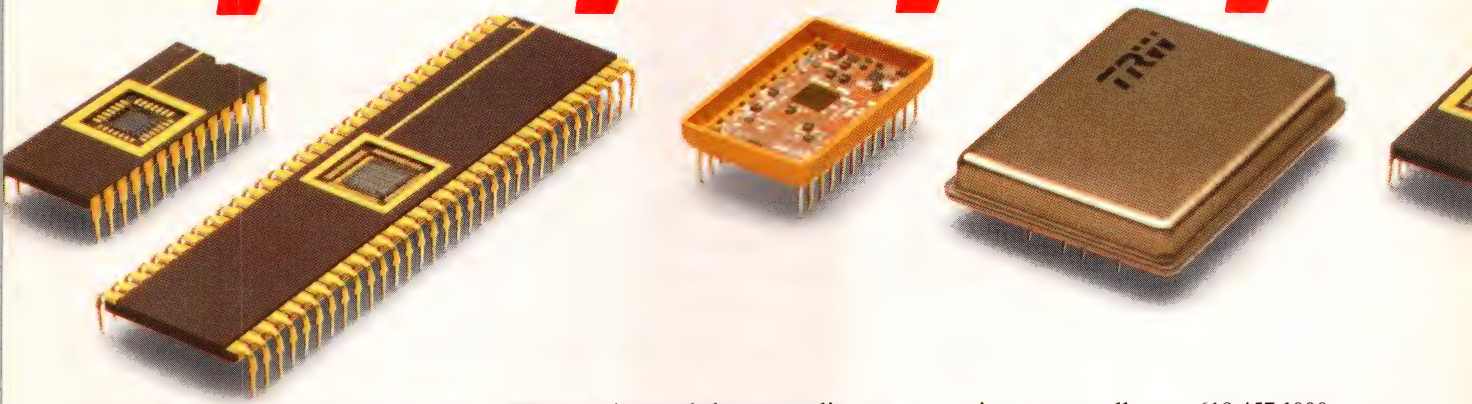

TRW LSI Products makes it easy to select the high-speed A/D converter that best fits your needs. Our growing family of flash converters offers hybrid and monolithic solutions for your 8- and 9-bit applications.

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THC1068	Hybrid	8-bits	25MSPS
TDC1049	Monolithic	9-bits	30MSPS
THC1069	Hybrid	9-bits	30MSPS
TDC1020	Monolithic	10-bits	20MSPS

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CIRCLE NO 203

NEWS BREAKS: INTERNATIONAL

AGREEMENT COMBINES WORLDWIDE ASIC PRODUCTION AND DESIGN TOOLS

Philips Components (Eindhoven, The Netherlands, TLX 51573) and VLSI Technology Inc (San Jose, CA, (408) 942-1810) have entered into an agreement under which Philips will make its worldwide ASIC-production facilities available to VLSI Technology, and VLSI Technology will make its IC-design software available to Philips. The agreement embraces CAD software, foundry services, gate arrays, and cell libraries. In addition to providing its design tools for use in Philips's semiconductor operations, VLSI Technology will license its software to interested Philips customers and to Philips's IC-user divisions. In return, Philips will provide VLSI Technology with worldwide foundry services and will provide qualification for 1.5-μm technology in the second half of 1988.—Peter Harold

JAPANESE ULSI SYMPOSIUM OFFERS ENGLISH TRANSLATION

The Seventh International Symposium on ULSI Ultra Clean Technologies will be the first in the series to offer simultaneous translation into English, thanks to Mitsubishi International Corp, which is cosponsoring the event. The previous six symposia of this series were held entirely in Japanese. The meeting, organized by the Institute of Basic Semiconductor Technology Development of Japan, will take place from July 21 through 23, 1988, in the Keidanren-Kaikain conference center in Tokyo, Japan.

The principal topic of this year's symposium will be submicron ULSI processing. The conference will feature speakers from industry and research organizations throughout Japan; its organizers are Tadahiro Ohmi, a professor in the Solid State Electronics Laboratory of Tohoku University, and Takahisa Nitta, department manager of the Device Development Center of Hitachi Ltd. The attendance fee is $1500. To obtain more information or to register for the symposium, contact Yasuo Tsurumi or Bill Chapman at Mitsubishi International Corp (Fremont, CA, (415) 651-9931).—Joanne Clay

LOW-COST TIMING ANALYZER SIMPLIFIES TRIGGER SETUP

Targeting hardware engineers who need a low-cost, high-performance timing analyzer, the LAL logic analyzer from Rohde & Schwarz GmbH (Munich, West Germany, TLX 523703; in the US: Lanham, MD, (301) 459-8800) provides sixteen 100-MHz variable-threshold input channels or eight 200-MHz channels. To maximize the trace length, the analyzer employs transitional timing and incorporates a glitch-capture facility that can capture glitches as short as 3 nsec. Its internal timebase resolution ranges between 5 nsec and 4 μsec. To clock the analyzer externally at frequencies as high as 100 MHz, you can add an optional clock probe with three clock qualifiers. To simplify instrument setup, the analyzer provides you with a menu of 13 predefined trigger functions for which you can specify the timing and trigger words. The instrument's graphical display of the trigger conditions makes trigger setups easy to understand. The LAL analyzer is priced at DM 12,000.—Peter Harold

ROBOT-TEACHING LANGUAGE IS THE FIRST TO BE BASED ON JAPANESE

The industry's first robot-teaching language based on Japanese has been developed by Kobe Steel Corp and Yokogawa Hewlett-Packard. The teaching language lets an operator use a personal computer to interactively teach or program a robot in Japanese. At present, all the robot-teaching languages used in Japan are based on English. In this new system, all the programming words are Japanese, and the command-input structure and programming grammar are based on Japanese grammar. The system costs ¥1,500,000 (approximately $12,000).—Joanne Clay

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LOW PASS Model *LP-	10.7	21.4	30	50	70	100	150	200	300	450	550	600	750	850	1000
Min. Pass Band (MHz) DC to	10.7	22	32	48	60	98	140	190	270	400	520	580	700	780	900
Max, 20dB Stop Frequency (MHz)	19	32	47	70	90	147	210	290	410	580	750	840	1000	1100	1340

Prices (ea.): P $9.95 (6-49), B $24.95 (1-49), N $27.95 (1-49), S $26.95 (1-49)

HIGH PASS Model *HP-		50	100	150	200	250	300	400	500	600	700	800	900	1000
Pass Band (MHz)	start, max.	41	90	133	185	225	290	395	500	600	700	780	910	1000
	end, min.	200	400	600	800	1200	1200	1600	1600	1600	1800	2000	2100	2200
Min. 20dB Stop Frequency (MHz)		26	55	95	116	150	190	290	365	460	520	570	660	720

Prices (ea.): P $12.95 (6-49), B $27.95 (1-49), N $30.95 (1-49), S $29.95 (1-49)

*Prefix P for pins, B for BNC, N for Type N, S for SMA   *example:* PLP-10.7

C105 REV.D

CIRCLE NO 206

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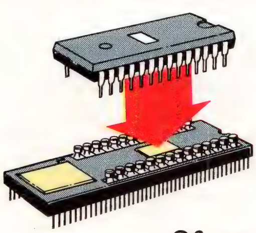
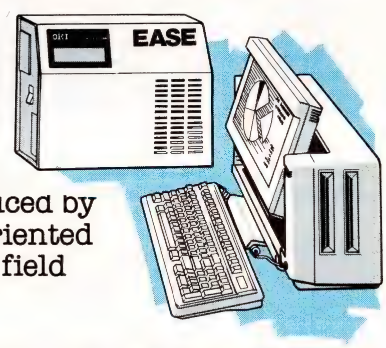


Of course, OKI's 66301 MCU is solidly backed with a full-scale development system. For realtime in-circuit emulation (ICE), use the **NXC** EASE system. The portable EASE package includes your ICE hardware, user's manual, plus complete assembler and debugger software for both MSDOS and VMS. With a compatible high-efficiency C-Compiler option as well. All available from OKI. All part of the **NXC** solution to high-end multitasking applications, produced by the most system-oriented technologies in the field today.



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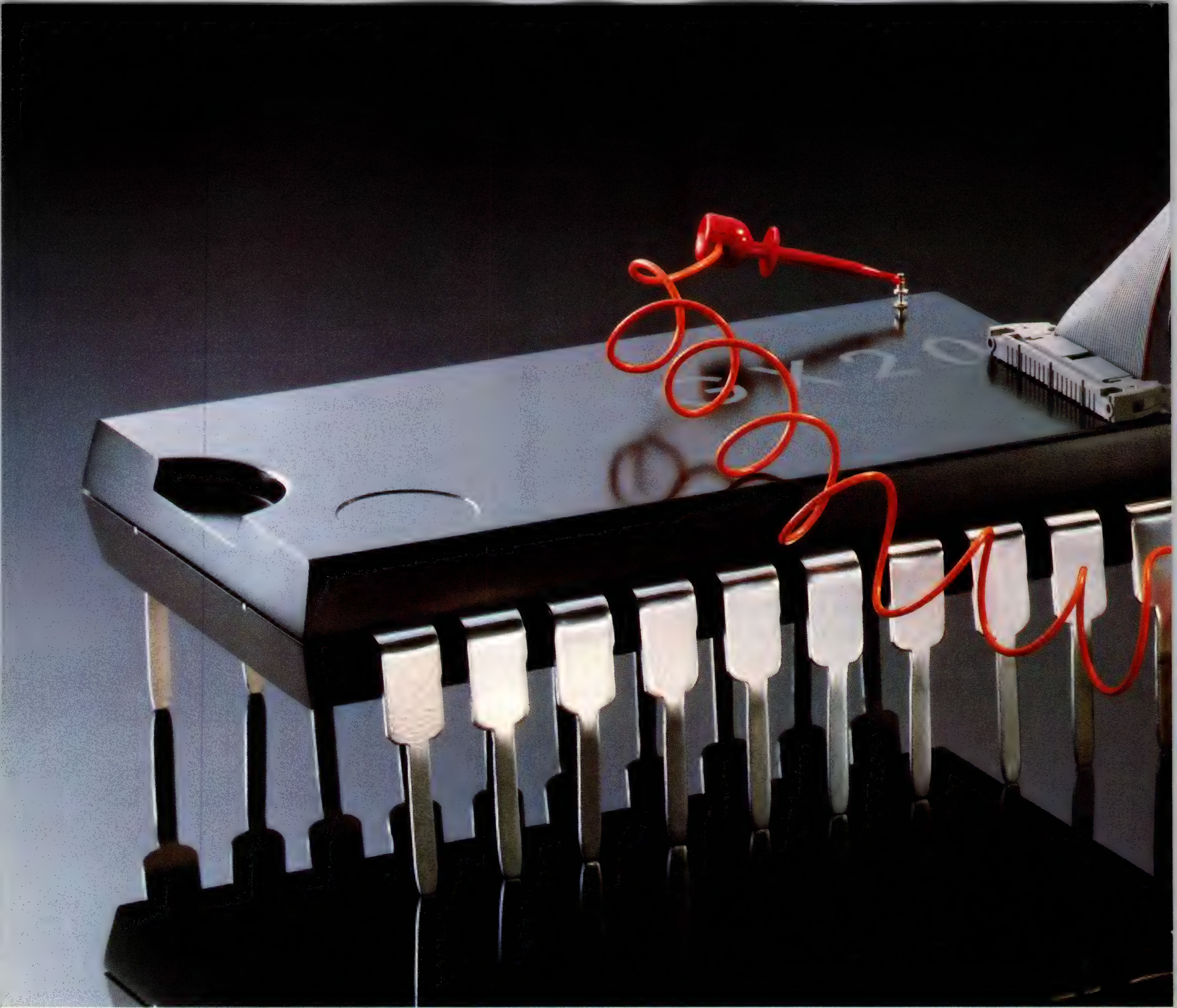

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Teradyne now has a simple answer to this complex testing problem. The A500 Analog VLSI Test System. It's the first of a new generation of systems specifically for AVLSI "system silicon" devices. A test system that can help you cut critical product development time by months or even years.

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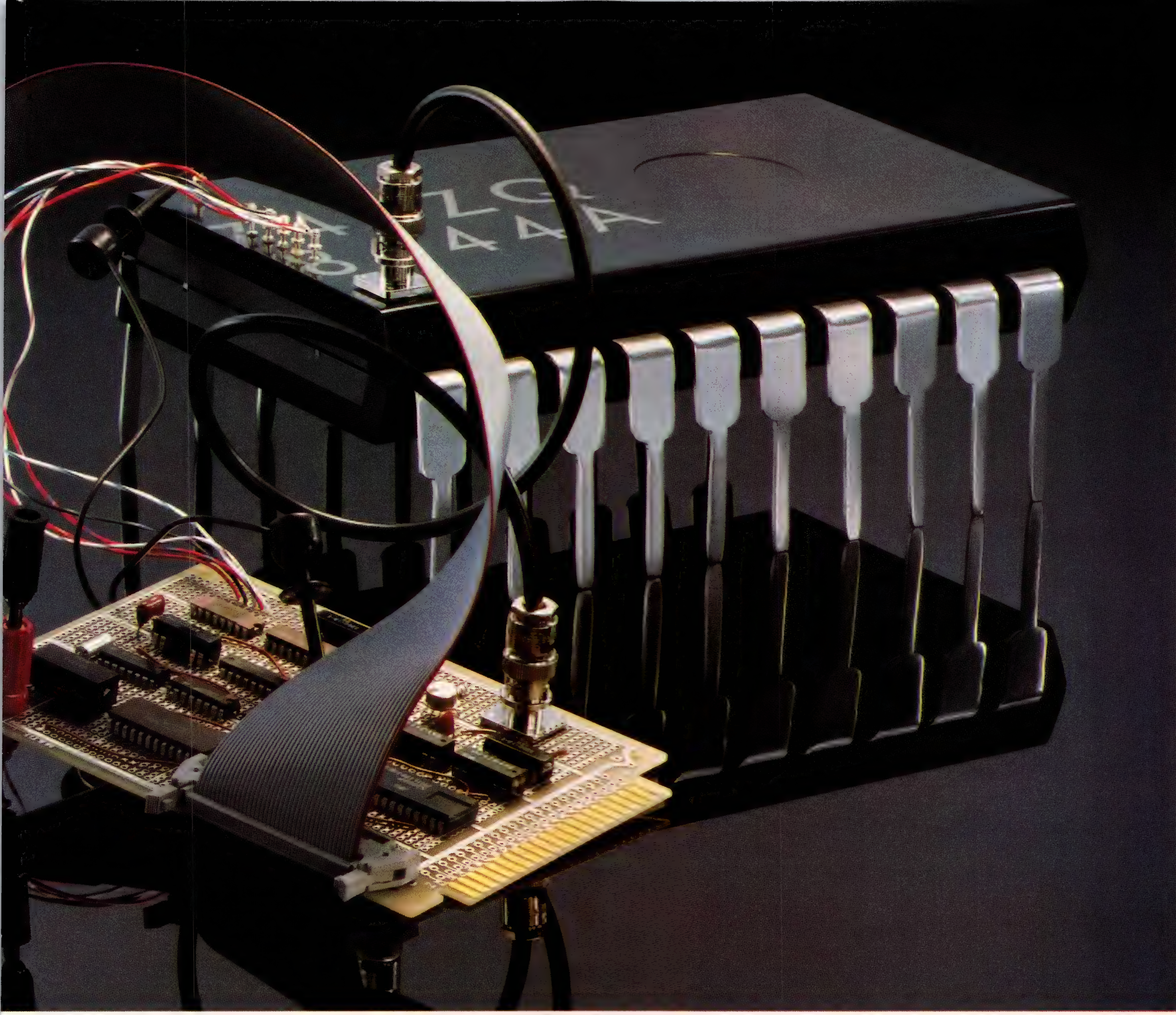
The heart of the A500 is Teradyne's unique Vector Bus II architecture. It integrates analog and digital VLSI test capability at the system level. Which means you won't have to build special applications hardware for every new device you design. Vector Bus II eliminates that costly custom-work bottleneck



Why accept it in an Analog VLSI Test System?

with such features as TimeMaster™ Synchronization, Mixed-Signal Event Control, and MultiSource Data Mixing.

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The A500 also revolutionizes program development. Our IMAGE™ (Interactive Menu-Assisted Graphics Environment) software gives you graphics programming as powerful as device designers' CAD/CAE tools. Using a mouse to control multiple windows, pop-up menus and software "power tools," you move ideas rapidly from mind to screen. And much faster to market.

Teradyne's new A500 is the only test system with the features you need to win the race for Analog VLSI market opportunities. To find out more, call Beth Sulak at (617) 482-2700, ext. 2746. Or call your nearest Teradyne sales office or write: Teradyne, Inc., 321 Harrison Avenue, Boston, MA 02118.

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CIRCLE NO 208

SIGNALS & NOISE

Praise for Feerst was ill-placed

From this letterhead you can conclude that I am indeed a *professor*, that dirty word in Irwin Feerst's vocabulary. (That I was in industry for 42 years before becoming a professor is irrelevant; that I have founded a company since becoming a professor is also irrelevant.) My grandparents were *immigrants*—another dirty word in Irwin Feerst's vocabulary—and so was Charles Steinmetz.

I was a member of a CIO union for technical professionals in my younger years. I was also a member of the IRE (Institute of Radio Engineers) and the AIEE (American Institute of Electrical Engineers), which is now merged with the IEEE, perhaps before Irwin was wetting his diapers, I suppose.

I can tell the difference between a trade union and a professional scientific society, thank you. But Irwin wants to go even further. He wants to adopt the medieval guild practices the AMA was once accused of. The nation is in a crisis, commercial and technical, and all Irwin can suggest is to kill the bloody foreigners and tell the young Americans not to study engineering (see his latest bulletin). What kind of America does he want, anyhow? "Fortress America," locked in behind an electronic curtain where we can contemplate our navels and buy Far Eastern VCRs, cars, and computers?

Yes, the IEEE would really face "extinction," along with the entire profession, if the likes of Irwin had their way with it! It was ill-placed of Jon Titus to call for contributions to this loose cannon in an editorial ("IEEE faces extinction," EDN, February 4, 1988, pg 53).

Morton Nadler
Professor
College of Engineering
Virginia Polytechnic Institute and State University
Blacksburg, VA

Forth comes forth

A letter from reader Robert Johnson (EDN, February 18, 1988, pg 34) decried the omission of Forth cross compilers in my article "HLL cross compilers speed 1-chip-μC software development" (EDN, December 24, 1987, pg 126). In response to that letter, several helpful readers provided us with information regarding Forth cross compilers (Forth vendors prefer to call them cross target compilers) for 1-chip μCs. **Table 1** lists some of the

TABLE 1—REPRESENTATIVE FORTH COMPILERS FOR 1-CHIP μCs

VENDOR	PRODUCT	TARGET μC	PRICE	ADDRESS
BRYTE COMPUTERS	BRYTE FORTH 8031	8031	$235	BOX 46 AUGUSTA, ME 04330 (207) 547-3218
FORTH INC	CHIPFORTH	8051, 8096, 6801	$3250	111 N SEPULVEDA BLVD MANHATTAN BEACH, CA 90266 (213) 372-8493 TLX 275182
INNER ACCESS CORP	FORTH SUPER8 METACOMPILER	SUPER8	$295	BOX 888 BELMONT, CA 94002 (415) 591-8295 TLX 4943275
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Part	Power	Page Mode	Ready/Busy	Packaging	Screening
52B33 (NMOS)	110 mA (active) 40 mA (stand-by)	No	No	DIP LCC	883 Class B
2864 (NMOS)	110 mA (active) 40 mA (stand-by)	No	Yes	DIP LCC PLCC Flat Pack	883 Class B JAN
28C64 (CMOS)	**50 mA (active) 150 μA (stand-by)**	**64 bytes**	**No**	**DIP LCC PLCC**	**883 Class B**
28C65 (CMOS)	**50 mA (active) 150 μA (stand-by)**	**64 bytes**	**Yes**	**DIP LCC PLCC**	**883 Class B**

Note: All parts have read access time of 200 ns.

If you're looking for ways to cut the power needs on designs, SEEQ has some high density CMOS answers.

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available compilers.

In addition, Development Associates (Santa Ana, CA, (714) 835-9512) offers the Future86 compiler, which was derived from the Forth language. It generates ROMable code for processors (such as NEC's V-25 and V-35 1-chip μCs) that execute 8086 instructions. Future86 costs $349.—*Steve Leibson*

Correction

Please note a correction to the News Break on the HP/Sony proposed DAT (digital audio tape) data-storage standard (EDN, March 31, 1988, pg 21). The proposal supports a data-transfer rate of 11M bytes/minute (not 11M bytes/sec). According to Alan Richards of Colorado Memory Systems (Loveland, CO), who spotted the error, several tape-drive vendors believe the slow data rate will be a problem for peripherals based on the definition.

YOUR TURN

EDN's Signals and Noise column provides a forum for readers to express their opinions on issues raised in the magazine's articles or on any topic that affects the engineering industry. Send your letters to the Signals and Noise Editor, 275 Washington St, Newton, MA 02158. We welcome all comments, pro or con. All letters must be signed, but we will withhold your name upon request. We reserve the right to edit letters for space and clarity.

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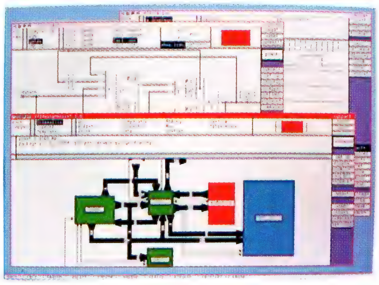
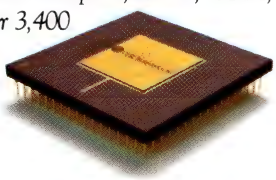


The Concept Express Design System's highly productive logic tools and silicon compilers were used to develop this very-large-scale ASIC. It incorporates a 2901 datapath, RAM, ROM, and over 3,400 gates of random logic.



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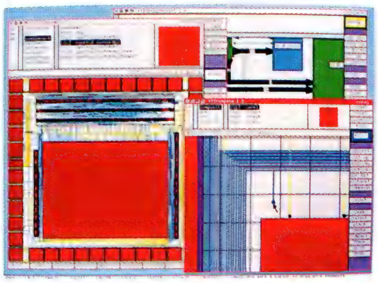

This highly-integrated design combines control logic, a register file, a refresh counter, and five peripheral chips onto a die size of 275x315 mils. The logic design, layout, and verification were completed in only 12 weeks.

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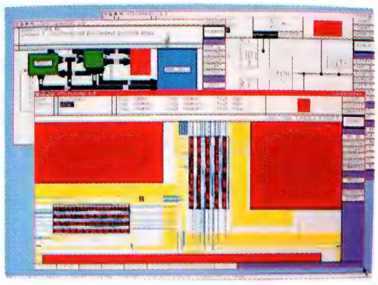

This design integrates all the peripheral chips for an AT computer with six megacells and control logic. Using the Silicon Express Design System, logic and physical designs like these can be implemented in under two man months.

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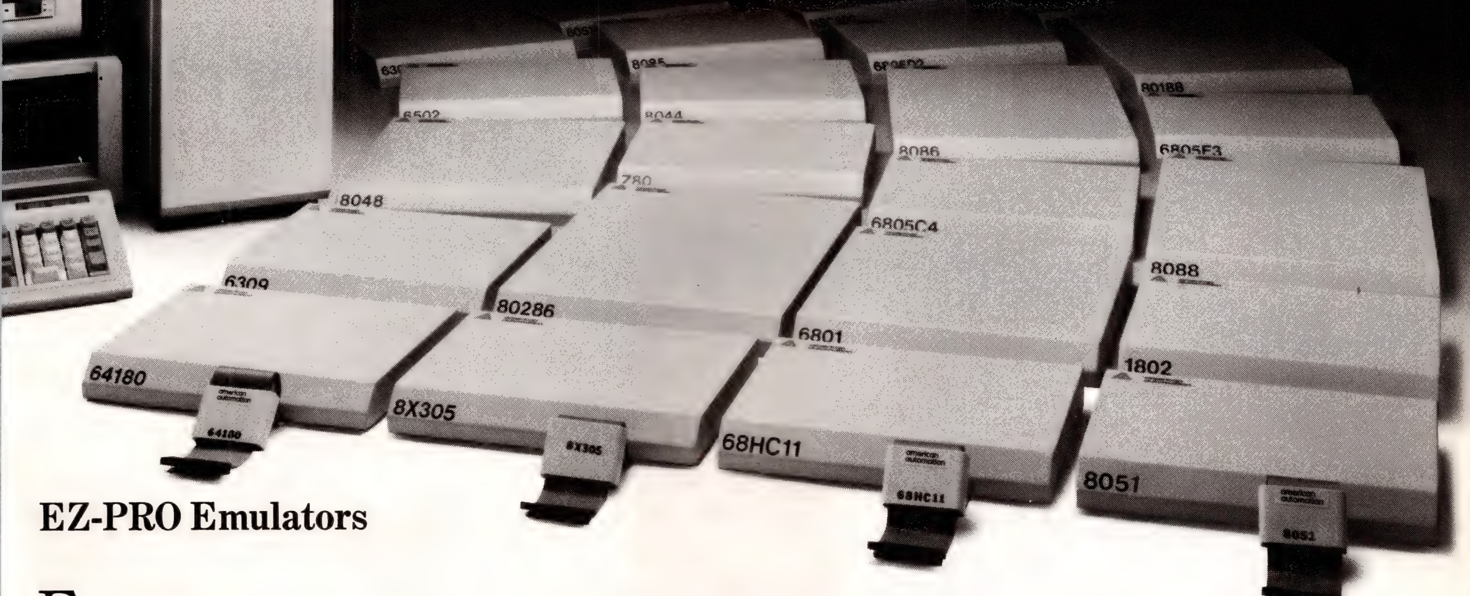

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8088	8039	68HC11A8	6802	6301Y	6505	CDP6805C4	Z180
80186	8344		68B02	6303R	6506	CDP6805C8	Z8001
80188	8048	68000	146805E2	6305V	6507	CDP6805D2	Z8002
80286	8049	68008	6803	63705	6512	CDP6805E3	
	8050	68010	6808	6309	6513		
	8051		68B08	6309E	6514		
	8085A		6809	64180R0	6515		
	8085A2		6809E	64180R1			
	8096/97		68B09				
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*Assumes EZ-PRO Development Station connected to MSDOS host.

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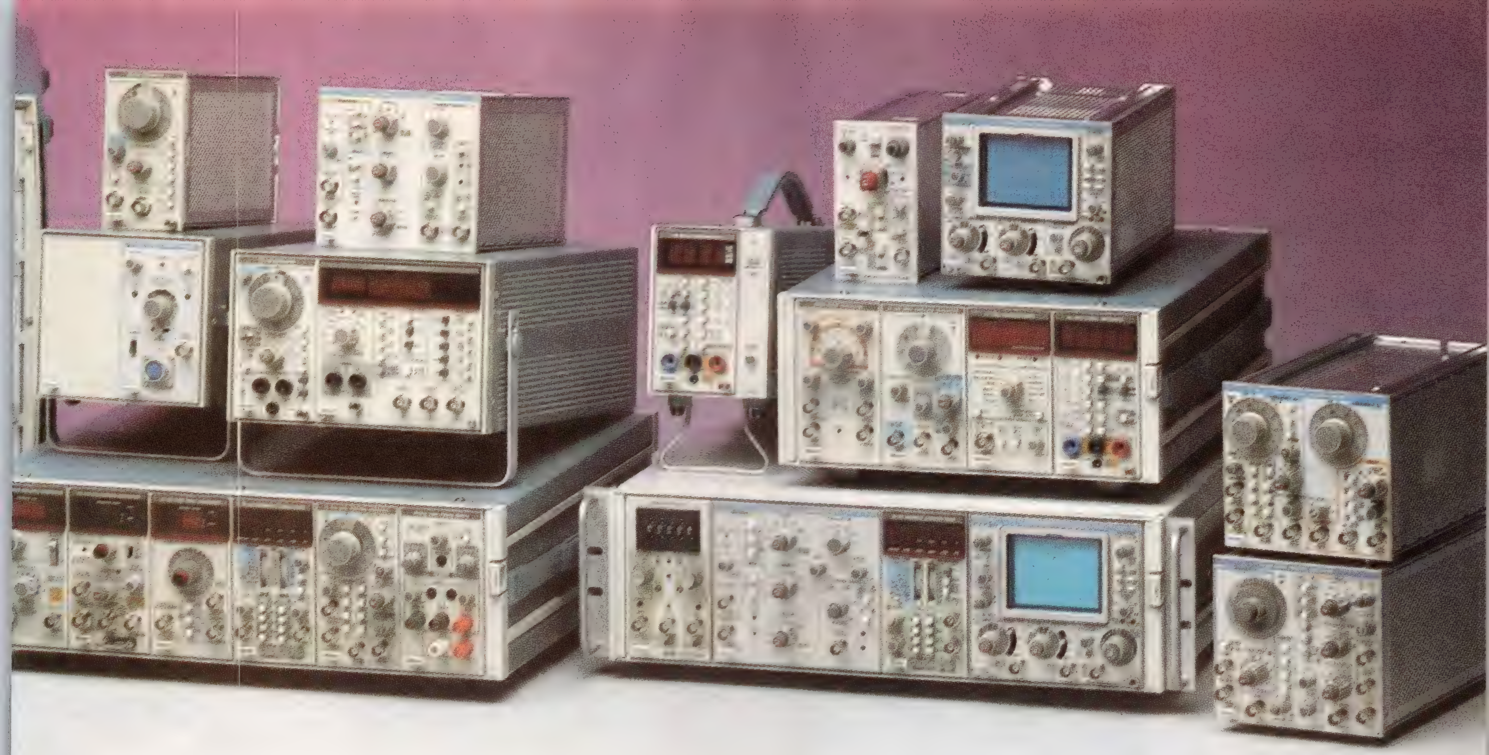

logarithmic and arbitrary sweeps, with any sweep usable in continuous, triggered, gated or burst mode. Users can receive instant frequency readout of breakpoints, notches, or response anomalies.

The applications are wide open. Use the AFG 5101 to drive sensors, timers, and other R&D equipment. To simulate metal stress or vibration characteristics. To teach waveform theory to students. And much more.

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(Center photo) The AFG 5101 can be ordered in either monolithic version, top right, or as a plug-in for the TM 5000 series mainframes, top left. Or, combine it with the DM 5010 4.5 Digit Multimeter and DC 5009 135 MHz Digital Counter within a TM 5006 mainframe (EBS 5002), as shown at bottom, and take 10% off the normal catalog price.

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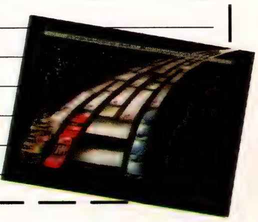

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CALENDAR

Nepcon East, Boston, MA. Cahners Exposition Group, 1350 E Touhy Ave, Des Plaines, IL 60018. (312) 299-9311. June 14 to 16.

IEEE COMPASS '88 (3rd Annual Conference on Computer Assurance), Gaithersburg, MD. Frank Houston, COMPASS '88, Box 5314, Rockville, MD 20851. (301) 443-5020. June 27 to 30.

Worst-Case Circuit Analysis (seminar), Honolulu, HI. Design and Evaluation, 1000 White Horse Rd, Suite 304, Voorhees, NJ 08043. (609) 770-0800. July 11 to 13.

CASE '88 (2nd International Workshop on Computer-Aided Software Engineering), Cambridge, MA. Pamela Meyer, Index Technology Corp, 1 Main St, Cambridge, MA 02142. (617) 494-8200, ext 1988. July 12 to 15.

Siggraph, Atlanta, GA. Barbara Voss, Robert P Kenworthy Inc, 866 United Nations Plaza, Suite 424, New York, NY 10017. (212) 752-0911. August 1 to 5.

Midcon, Dallas, TX. Electronic Conventions Management, 8110 Airport Blvd, Los Angeles, CA 90045. (800) 421-6816; in CA, (213) 772-2965. August 30 to September 1.

Surface Mount '88, Marlborough, MA. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. August 30 to September 1.

Modern Electronic Packaging (seminar), Santa Clara, CA. Technology Seminars, Box 487, Lutherville, MD 21093. (301) 269-4102. September 7 to 9.

12th International Fiber Optic Communications and Local Area Networks Exposition, Atlanta, GA. Information Gatekeepers, 214

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Harvard Ave, Boston, MA 02134. (800) 323-1088; in MA, (617) 232-3111. September 12 to 16.

Worst-Case Circuit Analysis (seminar), Boston, MA. Design and Evaluation, 1000 White Horse Rd, Suite 304, Voorhees, NJ 08043. (609) 770-0800. September 12 to 14.

Connector and Interconnection Technology Symposium, Dallas, TX. Electronic Connector Study Group, 104 Wilmot Rd, Suite 201, Deerfield, IL 60015. (312) 940-8800. October 3 to 5.

Autotestcon, Minneapolis, MN. Steve Palmer, Unisys, 3333 Pilot Knob Rd, Eagan, MN 55121. (612) 456-2349. October 4 to 6.

Electronic Imaging Conference East, Boston, MA. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. October 4 to 6.

Frontiers '88: The 2nd Symposium on the Frontiers of Massively Parallel Computers, Fairfax, VA. Frontiers Symposium, Box 334, Greenbelt, MD 20770. October 10 to 12.

International Electronic Manufacturing Technology (IEMT) Symposium, Lake Buena Vista, FL. Bill Moody, 2529 Eaton Rd, Wilmington, DE 19810. (302) 478-4143. October 10 to 12.

Modern Electronic Packaging (seminar), Boston, MA. Technology Seminars, Box 487, Lutherville, MD 21093. (301) 269-4102. October 12 to 14.

Worst-Case Circuit Analysis (seminar), San Francisco, CA. Design and Evaluation, 1000 White Horse Rd, Suite 304, Voorhees, NJ 08043. (609) 770-0800. October 17 to 19.

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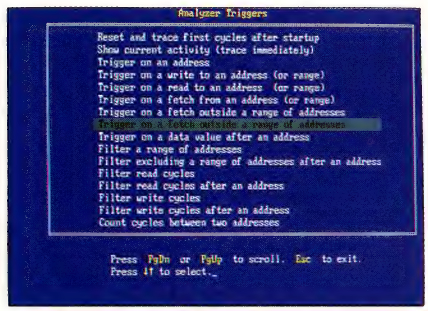

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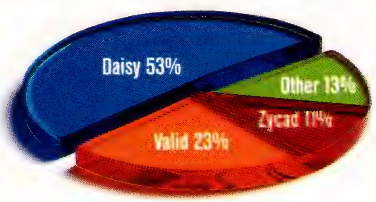

Simulation accelerator market share. Source: Prime Data, 1985 and 1986 unit shipments.

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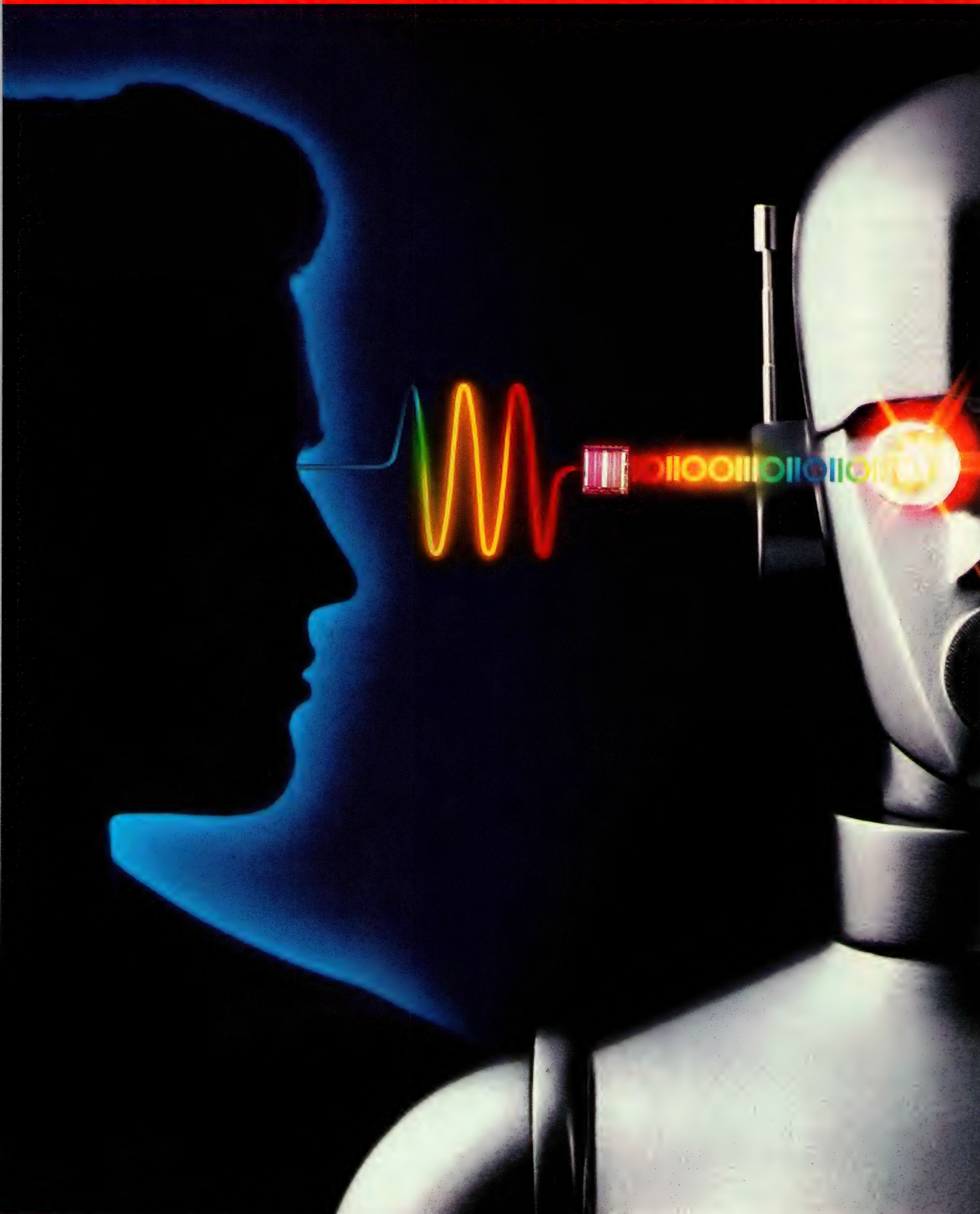

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These CMOS/SOS digital-to-analog converters operate from a single 5V supply at video speeds and can produce "rail-to-rail" output swings. Typical update rate is 50 MHz. Settling is fast (20 ns typical) to 1/2 LSB. "Glitch" energy is minimized by segmenting and bar graph decoding of upper 3 bits.

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ADC's	Res. Bits	Conv. Rate Hz	Power Diss. (MW)	Pkg. Leads	1K Price
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CA3306CE	6	10M	65	18	5.50
CA3306E/3306AE	6	15M	70	18	6.25/11.25
CA3318E/3318CE	8	15M	150	24	38.50/24.00
CA3310E/3310AE	10	150K	15	24	6.00/8.00
CDP68HC68A2E	10	10K	15	16	3.75
DAC's					
CA3338E/3338AE	8	50M	100	16	6.00/8.40
OP AMP	UGBW Hz	Slew Rate (X10)	I_{OUT} MA	Pkg Leads	1K Price
CA3450E	200M	300V/μSec	±75	16	2.70

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EDITORIAL

It's easy

Sometimes when I'm talking with youngsters about past scientific and engineering developments, one of them will say, "But things were so easy back then." It's hard for them to realize that doing something new or innovative is never easy. If it were easy, someone would already have done it. That sounds fairly obvious, but it's amazing how many people get suckered into thinking that new developments are easy. So, as far as new technology goes, only the hard things are left. But it has always been that way.

Today, most electrical engineers can put together a μP design in a few minutes. However, if you're a mechanical engineer facing your first μP system, it may not be so easy. If it were easy, it would have been done before now. Likewise, if a problem succumbs to a simple or easy solution, someone may already have solved it. I suppose there are some geniuses to whom everything appears easy, but most technological innovation comes from hard-working creative engineers who tackle tough jobs.

People use the word "easy" with abandon. Perhaps they think that telling us that a task is easy makes it so. On Saturdays when I'm working on home improvements and I have the TV on for background noise, I hear people say "easy" often. I watch two immaculately dressed people show me how easy it is to remodel a bathroom. They quickly plumb a sink and lay a new floor. The job looks easy and clean. To do it yourself, all you need is a set of books that describes how to do these *easy* jobs. I can imagine a less-than-handy person looking at his demolished bathroom and telling his wife, "If this looks bad, just think how it might look if we didn't have those books!"

People also use words such as "easy" to divert your attention from something else. For example, they'll tell you how easy it is to work with their company, when you really want to know how good their product is. One software company's ad describes its phone-support services and shows a $169,848 bill for the company's toll-free customer-service phone lines. It's nice that the company has such a strong commitment to customer service, but I'm still wondering why the product prompts 3700 phone calls each day. Another company brags: "Expanding our customer-service staff to over 80 people makes it easier for our customers to get through on the phone." I guess that although it's now easier to find someone to talk with, the product still has some real problems.

So, the next time you hear "easy," a mental alarm should go off. But watch out, "easy" doesn't travel alone. You'll often find it in the company of "unique," "impressive," "new," and "exciting."

Jon Titus
Editor

New high performance PC-based emulators from HP.

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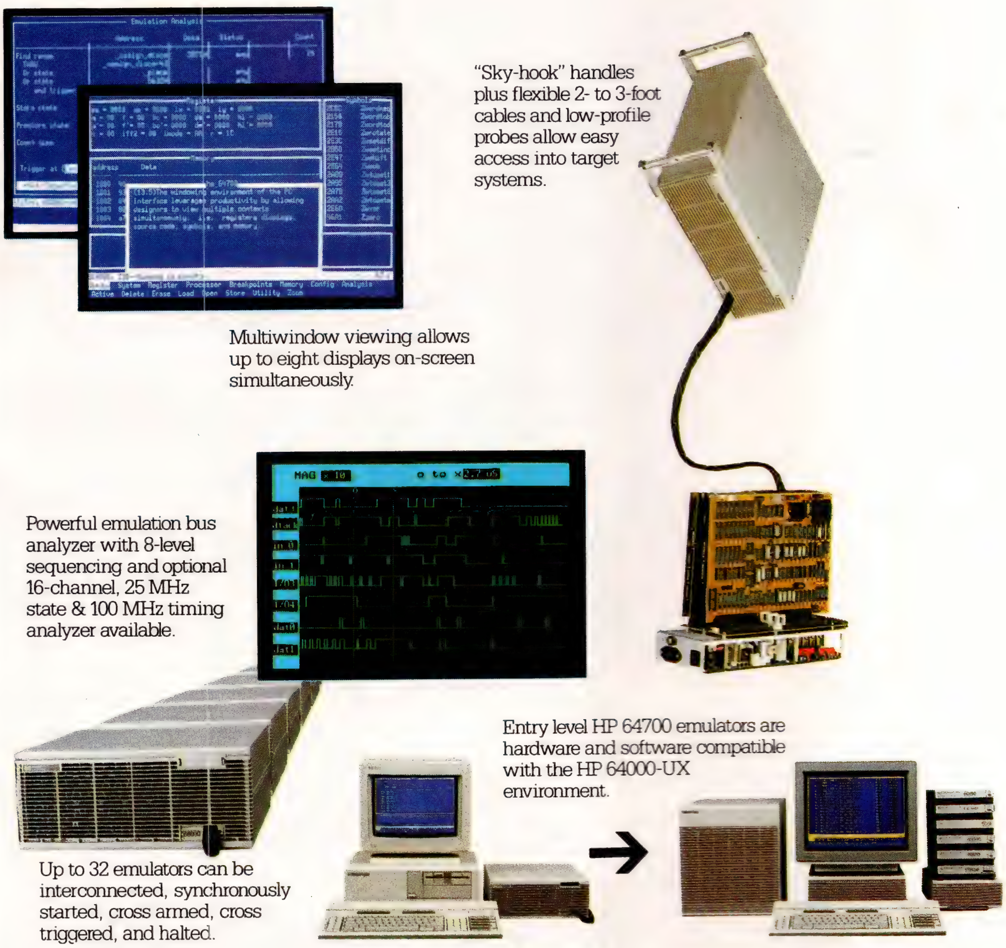

interface for superior download and upload speed, code coverage analysis for efficient software testing and design, host-independent portability, and compatibility with popular absolute file formats such as Tektronix and Intel hexadecimal and Motorola S record.

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CIRCLE NO 76

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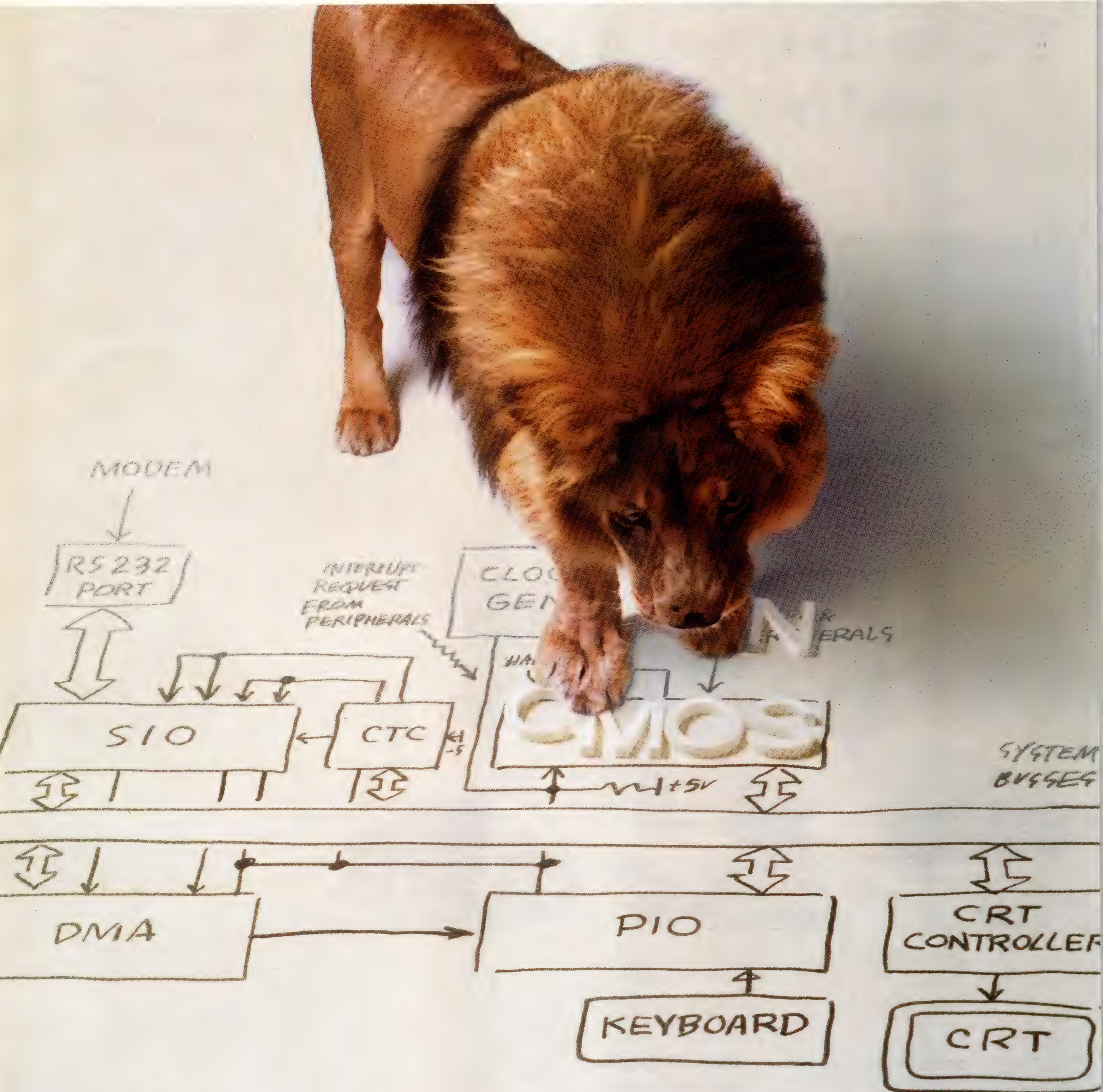

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TMPZ84C015A	F	Z80 MPU (4MHz) + CGC + CTC + PIO + SIO
TMPZ84C015A-6	F	Z80 MPU (6MHz) + CGC + CTC + PIO + SIO
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TMPZ84C10A	P,T, F	4MHZ	DIRECT MEMORY ACCESS CONTROLLER
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TMPZ84C30A	P,T, F	4MHZ	COUNTER TIMER CIRCUIT
TMPZ84C30A-6	P,T, F	6MHZ	COUNTER TIMER CIRCUIT
TMPZ84C40A	P	4MHZ	SERIAL I/O CONTROLLER
TMPZ84C40A-6	P	6MHZ	SERIAL I/O CONTROLLER
TMPZ84C41A	P	4MHZ	SERIAL I/O CONTROLLER
TMPZ84C41A-6	P	6MHZ	SERIAL I/O CONTROLLER
TMPZ84C42A	P	4MHZ	SERIAL I/O CONTROLLER
TMPZ84C42A-6	P	6MHZ	SERIAL I/O CONTROLLER
TMPZ84C43A	F	4MHZ	SERIAL I/O CONTROLLER
TMPZ84C43A-6	F	6MHZ	SERIAL I/O CONTROLLER
TMPZ84C44A	T	4MHZ	SERIAL I/O CONTROLLER
TMPZ84C44A-6	T	6MHZ	SERIAL I/O CONTROLLER
TMPZ84C60	P	4MHZ	CLOCK GENERATOR CONTROLLER
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CIRCLE NO 77

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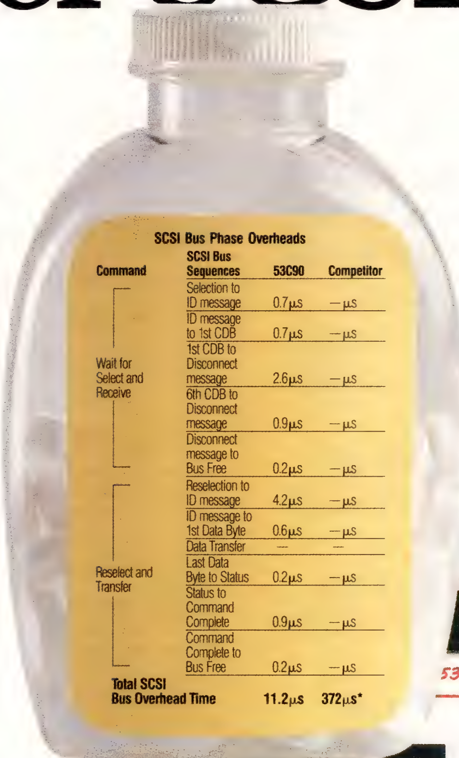

SCSI Bus Phase Overheads

Command	SCSI Bus Sequences	53C90	Competitor
Wait for Select and Receive	Selection to ID message	0.7µs	—µs
	ID message to 1st CDB	0.7µs	—µs
	1st CDB to Disconnect message	2.6µs	—µs
	6th CDB to Disconnect message	0.9µs	—µs
	Disconnect message to Bus Free	0.2µs	—µs
Reselect and Transfer	Reselection to ID message	4.2µs	—µs
	ID message to 1st Data Byte	0.6µs	—µs
	Data Transfer	—	—
	Last Data Byte to Status	0.2µs	—µs
	Status to Command Complete	0.9µs	—µs
	Command Complete to Bus Free	0.2µs	—µs
Total SCSI Bus Overhead Time		11.2µs	372µs*

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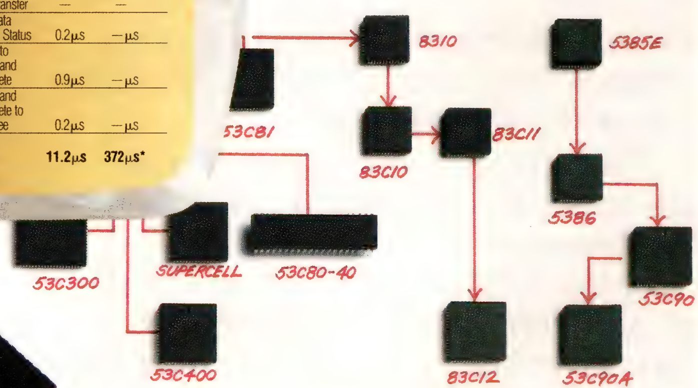

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*Electronics Magazine August 20, 1987 Pg. 65

CIRCLE NO 78

Fiber-optic ICs accelerate communication over data links

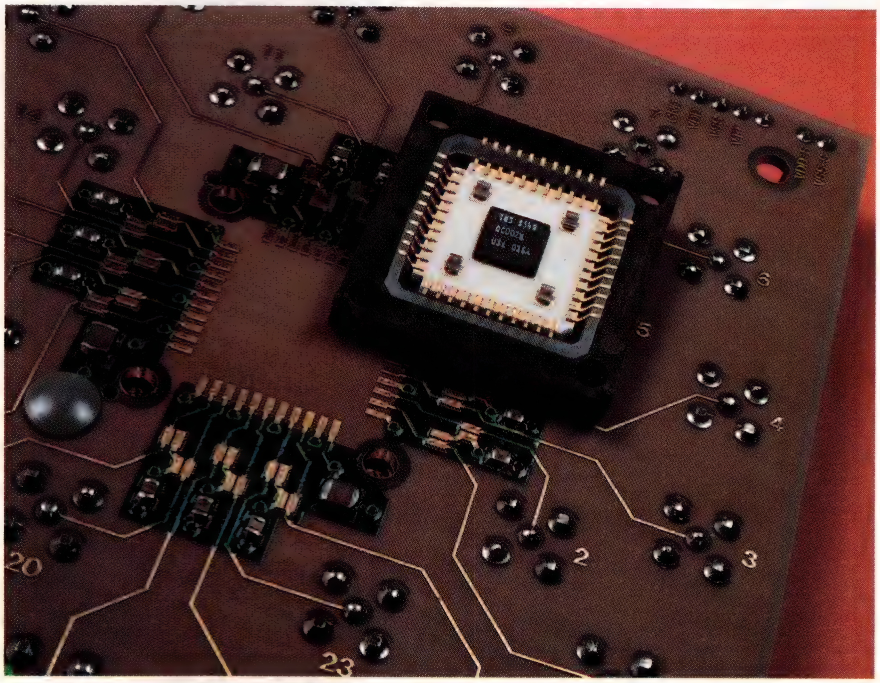
Dave Pryce, *Associate Editor*

The increasing need for high data rates and compatible architectures in fiber-optic systems—such as long-haul telecommunication systems, computer interconnections (LANs), and wideband video links—is ushering in a new generation of ICs. Among these ICs are devices that support emerging data-communication standards, as well as parts that extend the operation of fiber-optic systems well into the gigahertz range. Optical fiber itself has a virtually unlimited bandwidth, and to help you overcome fiber-optic systems' previous speed limitations, manufacturers are fabricating many of the new ICs in gallium arsenide (GaAs) instead of silicon.

Fiber-optic data-communication systems comprise two basic parts: The transmitter provides a light source for transmitting the data to the fiber, and the receiver converts the received light information to its original form. Excluding any encoding scheme, the basic transmitter for a digital fiber-optic system **(Fig 1)** consists simply of a multiplexer that converts the parallel input data to serial form, a driver for the laser diode or LED, and the diode itself.

The basic receiver consists of a PIN diode or avalanche photodiode (APD) that converts the light to a current, a transimpedance amplifier that converts this current to a voltage, a wideband amplifier that provides additional gain, a decision circuit (comparator) that works in conjunction with the clock-recovery circuit to restore the data, and a demultiplexer that changes the serial data back to its original parallel form.

A number of companies make one



This multilayer ceramic package, *the MLC44, was developed by TriQuint Semiconductor to enclose the company's TQ1135/TQ1136 multiplexer/demultiplexer devices and other GaAs ICs that operate at gigahertz frequencies.*

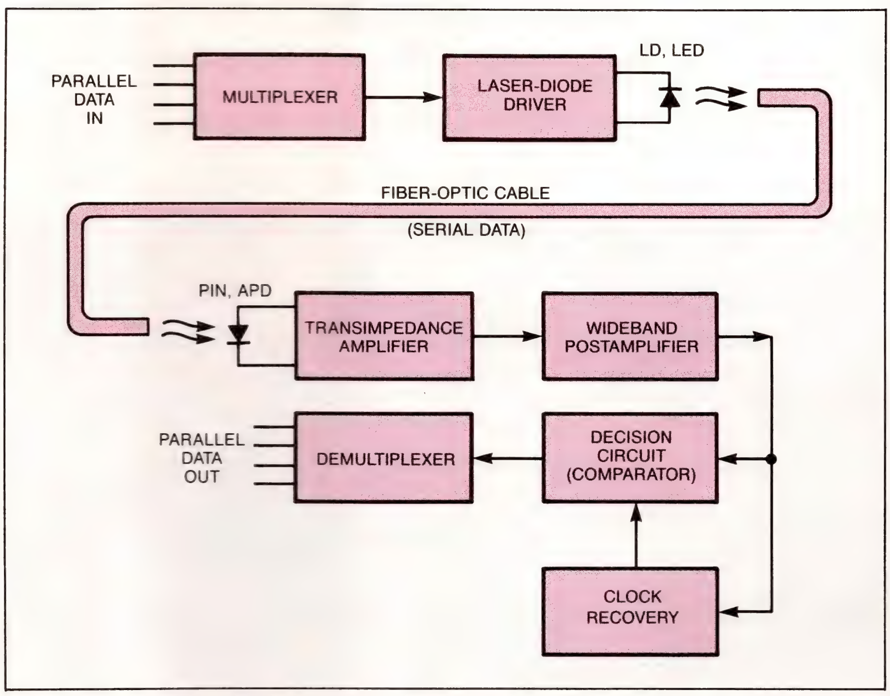


Fig 1—The basic building blocks of a fiber-optic system *appear simple, but they often control complex functions.*

or more of the basic transmitter and/or receiver building blocks. Anadigics, for example, manufactures transimpedance amplifiers, wideband amplifiers, a laser-diode driver, and a high-speed comparator that you can use as part of a clock-recovery circuit. A variety of multiplexers and demultiplexers is available from such companies as Microwave Semiconductor Corp, TriQuint Semiconductor, GigaBit Logic, and Vitesse Semiconductor.

Microwave Semiconductor and Signetics offer transimpedance amplifiers. Microwave Semiconductor also offers a laser-diode driver, and Signetics has a wideband amplifier and a PLL circuit for clock recovery. Micro Linear Corp sells a device called a "data quantizer," which is a combination wideband amplifier and comparator that operates between the transimpedance amplifier and the clock-recovery/decoder circuit in a receiver.

Typical of the new breed of GaAs multiplexers and demultiplexers are the TDMX-1501A (8:1 multiplexer) and the TDDX-1501A (1:8 demultiplexer) from Microwave Semiconductor Corp (**Fig 2**). The TDMX accepts eight synchronous, ECL-compatible inputs and translates them into a single high-speed digital output at a 1.5G-bps data rate. The chip provides a divide-by-8 clock that can synchronize other peripheral chips.

The TDDX accepts a synchronous, ECL-compatible, high-speed digital input as high as 1.5G bps and demultiplexes it into eight synchronous, ECL-compatible data-output streams. The TDMX's typical power dissipation is 2.4W; the TDDX's is 1.8W. Each chip features rise and fall times of 200 psec, and each comes in a 44-pin, 0.65-in. square ceramic package and sells for $225 (100). Both devices also come in lower-frequency versions: the 1.2G-bps and 850M-bps versions of each part cost $150 and $60, respectively.

A technology-exchange agreement between Microwave Semiconductor and TriQuint Semiconductor makes similar GaAs products from the two companies interchangeable. The TriQuint line includes 4:1, 8:1/16:1, and 12:1 multiplexers and their demultiplexer counterparts. The 4:1 and 8:1/16:1 types operate at data rates reaching 2G bps.

The TQ1135/TQ1136 12:1 multiplexer/demultiplexer is a 2-chip set that operates to 1.2G bps and has ECL-compatible inputs and outputs. The Sync input on the multiplexer chip allows the chip to synchronize with a low-speed system clock, and the Skip input on the demultiplexer chip provides data alignment by reframing the data. Each device comes in a surface-mount MLC44 package and costs $298 (100); 600M-bps versions are available at $192 each.

Vitesse Semiconductor also offers a 12:1/1:12 multiplexer/demultiplexer GaAs chip set, which operates at 1.25G bps. A unique feature of these devices is a self-test path that allows them to test each other—a first in the industry, the company claims. The VS8001 multiplexer has a Set input that synchronizes internal and external clocks. The VS8002 demultiplexer has a Skip input that aligns the 12-bit output with word boundaries. Both devices are ECL compatible, and both operate from standard ECL power supplies. The VS8001 and VS8002 come in 52-pin LCC packages and sell for $320 each (1000).

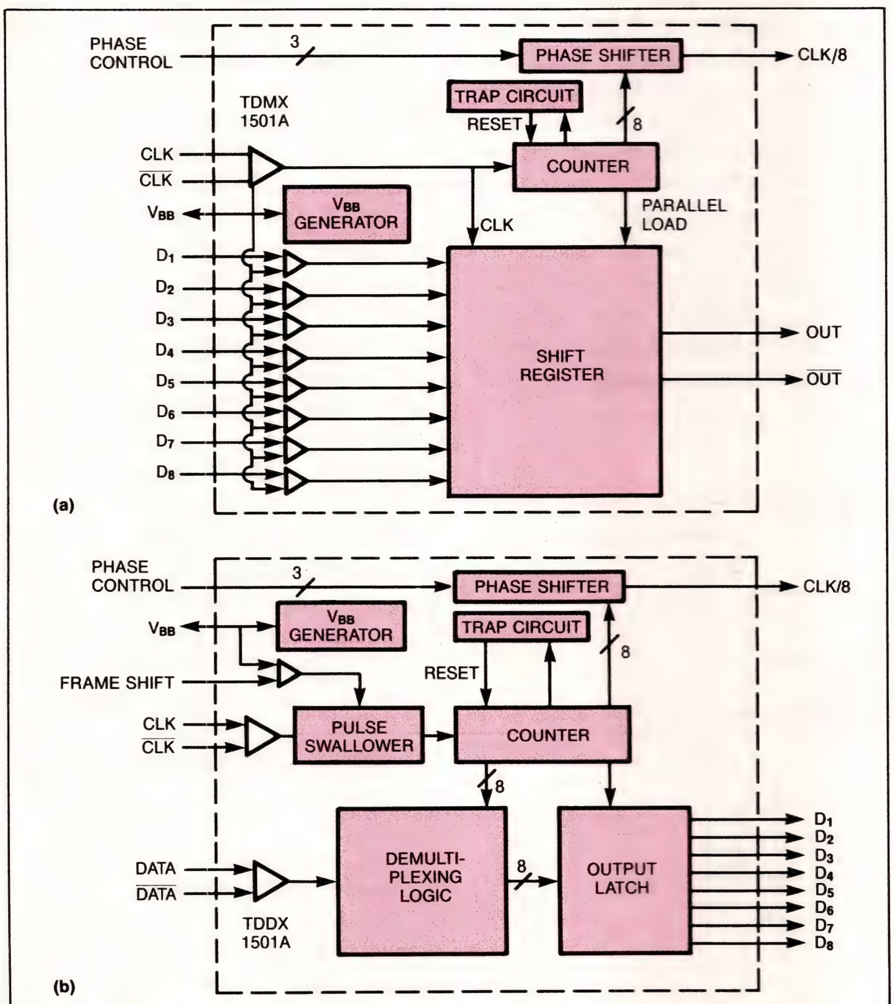


__Fig 2—The key components of digital fiber-optic systems__ are multiplexers __(a)__ and demultiplexers __(b)__. The TDMX and TDDX series from Microwave Semiconductor are representative of the devices available for parallel-to-serial conversion (multiplexing) and serial-to-parallel conversion (demultiplexing).

The transimpedance amplifier, the first active element in the receiver chain, converts the diode current to a voltage. Representative of these devices are the NE5212 from Signetics, the ATA30010 from Anadigics, and the TIA-1501B from Microwave Semiconductor. The Signetics device operates in the megahertz range; the Anadigics and Microwave Semiconductor parts function in the gigahertz range.

Fabricated in silicon, the NE5212 from Signetics has a −3-dB bandwidth of 120 MHz and a transimpedance gain of 14 kΩ, which make the device suitable for Ethernet and MAP applications. The NE5212 has a single-ended input and a differential output. A key feature of the chip is its extremely low input-noise spec: 2.5 pA/√Hz. In an 8-pin plastic DIP, the NE5212 costs $2.36 (100). A companion chip, the NE564, is a 50-MHz phase-locked loop (PLL) that you can use as clock-recovery circuit that recovers information from Manchester and other forms of encoding schemes. The NE564 costs $1.11 (100).

The GaAs transimpedance amplifiers from Anadigics and Microwave Semiconductor extend the operating frequencies of fiber-optic ICs into the gigahertz range. For example, Microwave Semiconductor's TIA-1501B **(Fig 3)** accepts an input from either a PIN diode or an APD, and it has a typical optical bandwidth of 1.2 GHz. A shunt gain-control FET across the input of the transimpedance amplifier operates in a normal automatic-gain-control (AGC) mode or acts as a high-frequency attenuator switch for electronic-warfare and instrumentation applications.

In addition to the AGC function, the TIA-1501B has an adjustable FET feedback network that you can employ to increase receiver sensitivity or to vary the transimpedance gain for the purpose of optimizing gain and bandwidth. A mirror FET adjacent to the feedback FET provides temperature compensation over −55 to +125°C. The part also features a 20-dB dynamic range and a buffered 50Ω output. Packaged in a 10-lead surface-mount flat pack, the TIA-1501B costs $80 (100).

Designed for long-haul communications, wideband video applications, and high-speed data links, the ATA30010 transimpedance amplifier from Anadigics features a 2.4-GHz analog bandwidth and a 3G-bps data-rate capability. At a 1-GHz operating frequency, the ATA30010 has 2500Ω input transresistance, a gain of 100, an output voltage of 1.4V p-p, and 50Ω output impedance. The input noise current of the device is 360 nA rms over the 10-MHz to 2-GHz bandwidth. In chip form, the ATA30010 costs $43.50 (1000).

Located between the transimpedance amplifier and the clock-recovery and demultiplexing circuits in a fiber-optic receiver, the ML4421 data quantizer from Micro Linear converts current-based analog data to digital pulses. The IC contains a dual-stage wideband (50-MHz) amplifier that drives a dc bias circuit, a threshold detector circuit, and a fast ECL comparator. These circuits provide automatic amplifier biasing, minimum signal-threshold discrimination, and ECL-compatible data outputs. The discriminator permits the disabling of the data-output comparator as well as providing a logic signal to establish the status of the fiber-optic link. The ML4421 operates from a 5V (TTL) supply or from a −5.2V (ECL) supply. The device costs $6.50 (1000) and is available in a 24-pin DIP or a 28-terminal PLCC.

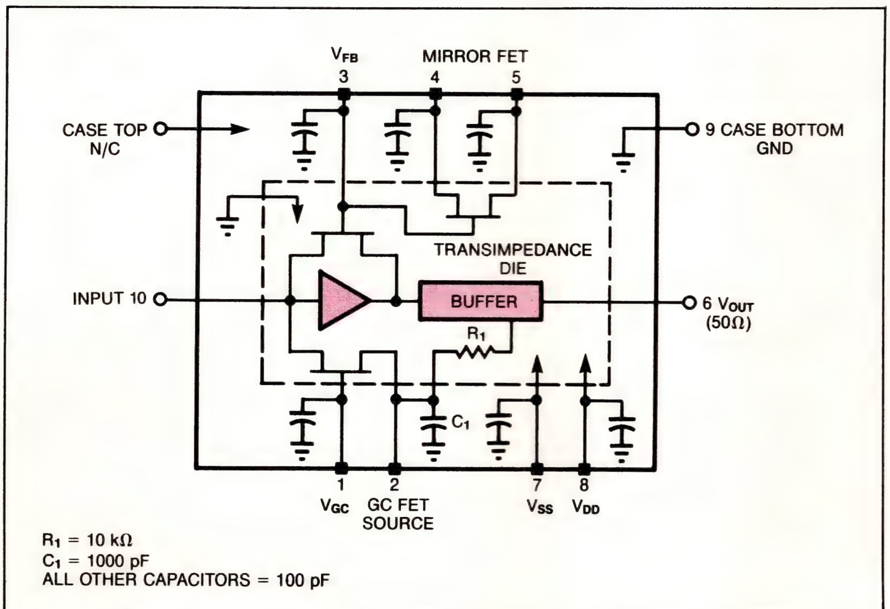
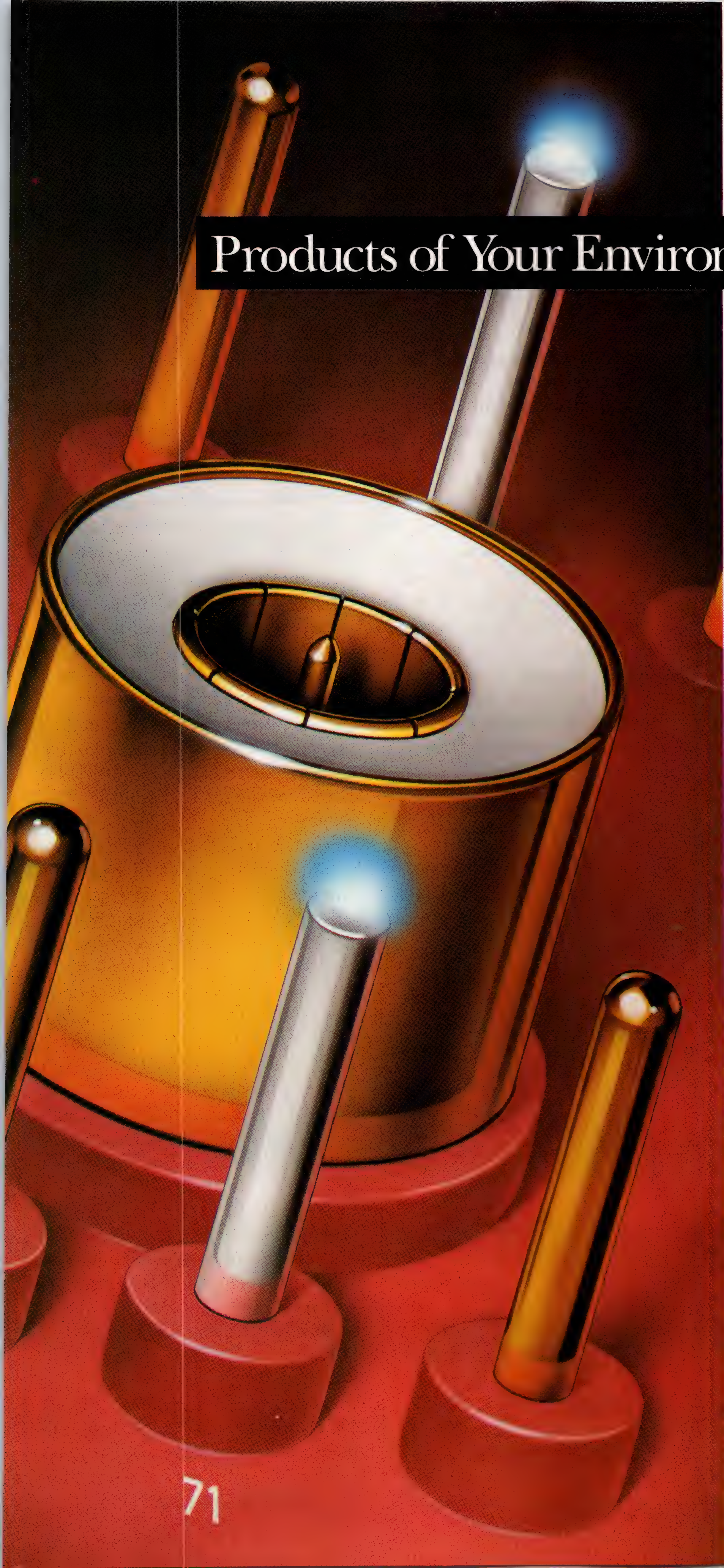


***Fig 3—A transimpedance amplifier resides at the front end** of a fiber-optic receiver, where it converts the current from a PIN diode or APD to a voltage. The TIA-1501B from Microwave Semiconductor is a typical transimpedance amplifier.*

Data recovery is complex

Clock and data recovery in a fiber-optic receiver is a half-analog, half-digital function that designers often find troublesome. GigaBit Logic believes its 16G040 GaAs chip solves the problem—particularly at data rates above 50M bps, which many previous ICs couldn't handle. The 16G040 works at data rates from 50M to 2.4G bps and contains the analog and digital circuitry needed to implement a PLL for both clock extraction from high-speed NRZ-format data streams, and data retiming and regeneration. Except for the loop filter, all the PLL components reside on chip.

Unlike conventional clock- and



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data-recovery circuits, which first filter the clock component from the incoming data and then retime the data by using the extracted clock, the 16G040 synchronizes an on-chip voltage-controlled oscillator (VCO) or external clock source directly with an incoming digital data stream, while simultaneously retiming and regenerating the data stream. During operation, the PLL is capable of unaided frequency acquisition, so it doesn't require any special circuits to pull the loop into lock when the incoming data rate differs from the initial clock frequency. The 16G040 sells for $75 (1000).

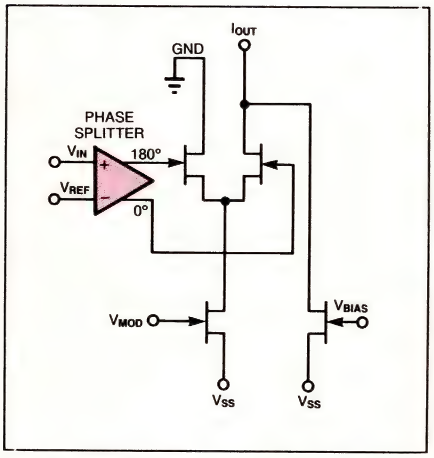

Fig 4—Fiber-optic transmitters need a laser-diode driver. *The ALD30010 from Anadigics, for example, includes a phase splitter for reverse isolation, and has four FET devices that provide the diode-drive and variable-modulation current.*

Laser-diode drivers

Back at the transmitter side of the fiber-optic system, both Microwave Semiconductor and Anadigics offer laser-diode drivers. The ALD30010 **(Fig 4)** from Anadigics contains four FETs and a 180° phase splitter. In addition to providing high reverse isolation, the phase splitter has sufficient gain to provide 0.6V p-p (0-dBm) input sensitivity for a single-ended input signal. The ALD30010 has a 10-kHz to 3-GHz frequency response and a standing-wave ratio of less than 2:1 over its full frequency range. A voltage-control function allows you to adjust the offset current from 0 to 70 mA and the modulation range from 0 to 30 mA. The ALD30010 costs $43.50 in chip form and $65 (1000) in an 8-pin flat pack.

Microwave Semiconductor also offers a high-performance laser-diode driver. Packaged in a 10-pin flat pack for use either in hybrid circuits or on pc boards, the LDCM-2001 ($125) has a minimum bandwidth of 2 GHz and a minimum NRZ data-rate capability of 3G bps. Its bias-current and modulation-current ratings are both 75 mA max. The power gain of the LDCM-2001 is 10 dB and is flat within ±0.5 dB over the 10-MHz to 2-GHz range. The device also offers the option of a single-ended or differential input and a laser-bias adjustment.

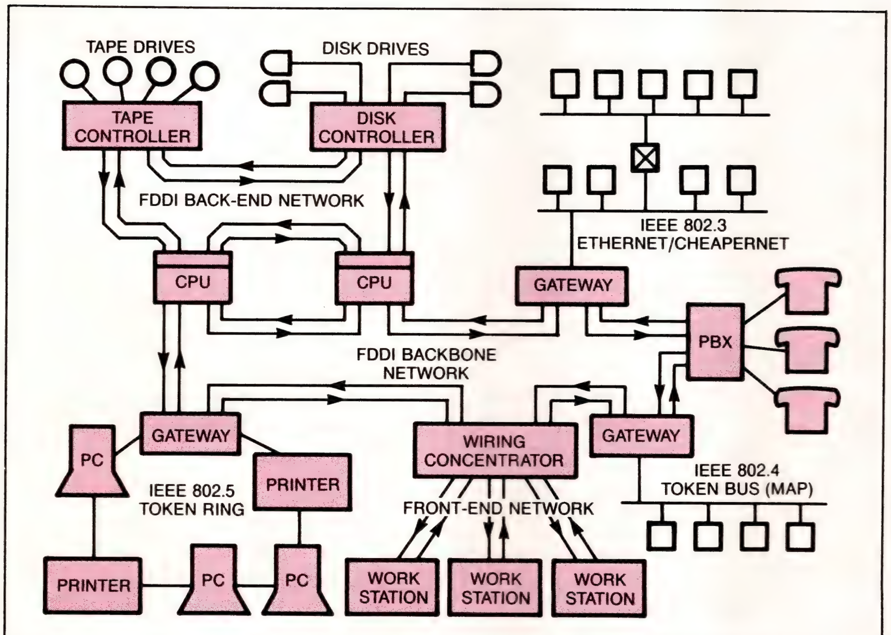

Fig 5—The Fiber Distributed Data Interface (FDDI) standard *supports many different network requirements, including those of the Token Ring, Token Bus (MAP), and Ethernet standards.*

ICs satisfy emerging standards

Although the functional building blocks for a fiber-optic system appear simple enough, the internal circuitry of the ICs that satisfy these functions is often quite complex. Further, many of the newer chips are designed to satisfy emerging optical-transmission standards that require even greater complexity and/or higher-frequency performance. Two examples of these newer standards are FDDI and Sonet.

The FDDI (Fiber Distributed Data Interface) standard grew from the need for a high-speed LAN interconnection among mainframes, minicomputers, and their associated peripherals. The FDDI standard provides for the same type of serial interconnection that most LANs use, and it extends the data rate to 100M bps and calls for the inherent noise immunity and security that fiber offers. FDDI supports a number of different network requirements **(Fig 5)**, including IEEE 802.3 (Ethernet), IEEE 802.4 (Token Bus), and IEEE 802.5 (Token Ring).

Probably the first company to develop devices for the FDDI standard was Advanced Micro Devices. Using a mixture of bipolar and CMOS technologies, AMD's $820 (100) Supernet 5-chip set provides all of the basic FDDI functions **(Fig 6)**. The chip set consists of three elements: a 3-port buffer-memory controller, a media-access controller, and a physical-link controller.

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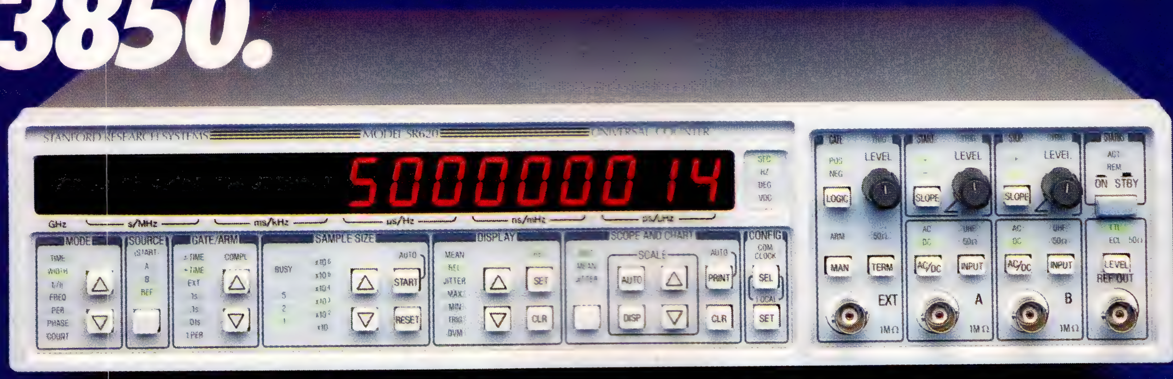

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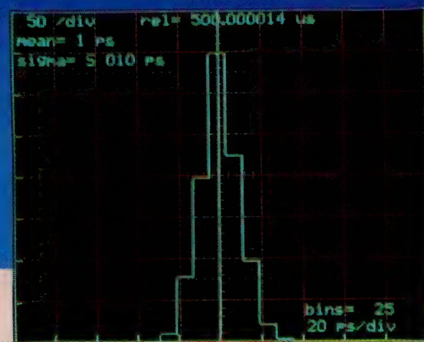

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The buffer controller, which comprises the Am79C81 RAM Buffer Controller (RBC) and the Am79C82 Data Path Controller (DPC), provides a host-system DMA interface, as well as the arbiter and control logic for local buffer memory. The RBC arbitrates requests from the host, node, and network, and generates the addresses necessary to make the buffer memory look like a FIFO buffer. The DPC performs byte-to-word funneling between the buffer memory and the network, and provides parity support for the local buffer-memory bus.

The media-access controller is the Am79C83 Formac (fiber-optic-ring media-access controller), which implements the FDDI link-layer and media-access-control functions. These functions include token management, system timer support, and response to system error conditions on the network.

Finally, Supernet implements the FDDI physical-layer controller with the 2-chip Endec (encoder/decoder). The Endec is responsible for recovery of the clock from the received signal data, data encoding and decoding, matching the transmit and receive clocks with the elasticity buffer (EB), and using a repeat filter to strip faults from the network. The Endec's two components are the Am7984 transmitter (ETX), which supports all station-interface functions as well as data transmission, and the Am7985 receiver (ERX), which contains only the receive section and uses the ETX for all station operations. The Endec's architecture minimizes crosstalk between the transmit and receive sections, which operate from different clocks.

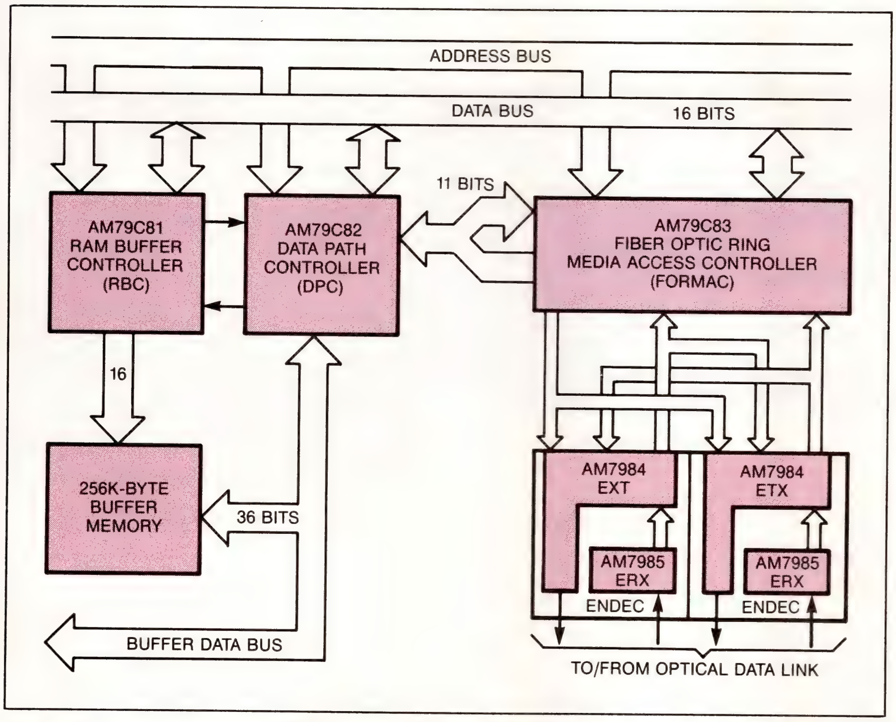

Fig 6—To implement the FDDI standard, AMD's Supernet 5-chip set uses a mixture of bipolar and CMOS technologies.

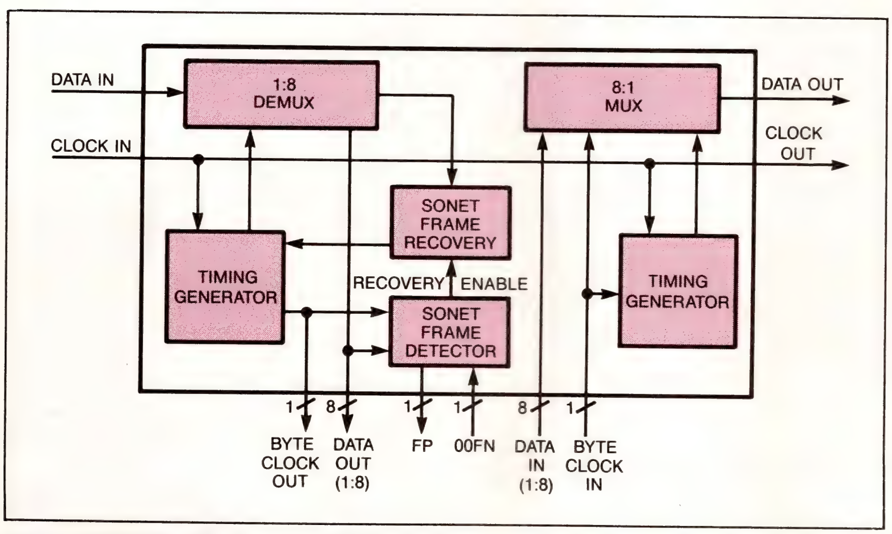

***Fig 7—Addressing the emerging Sonet (Synchronous Optical Network) standard** is the VS8010 chip from Vitesse. Sonet encompasses line rates from 51.84M to 2.48832G bps and allows system equipment from different manufacturers to communicate.*

High-frequency standard emerges

Another emerging standard, Sonet (synchronous optical network), was created to standardize transmission-line rates and architectures, which telecomm-equipment manufacturers have heretofore been unable to agree on. Long-haul systems currently communicate at different rates, such as 565 MHz, 1.2 GHz, or 1.7 GHz, but for now there's no clear standard. Sonet is expected to change this situation—companies such as AT&T, GTE, NEC, Northern Telecom, Siemens, and Rockwell plan to introduce Sonet-compatible equipment.

The Sonet standard encompasses line rates from 51.84M to 2.48832G bps. The standard will be useful not only in long-haul fiber-optic transmission, but also in local loops, and it may become the transmission-line standard for the Integrated Services Digital Network (ISDN). The present ISDN standard will prove too slow (it's in the kilobit range) to accommodate the amount of data that people and companies will want to transmit in the future. Sonet will

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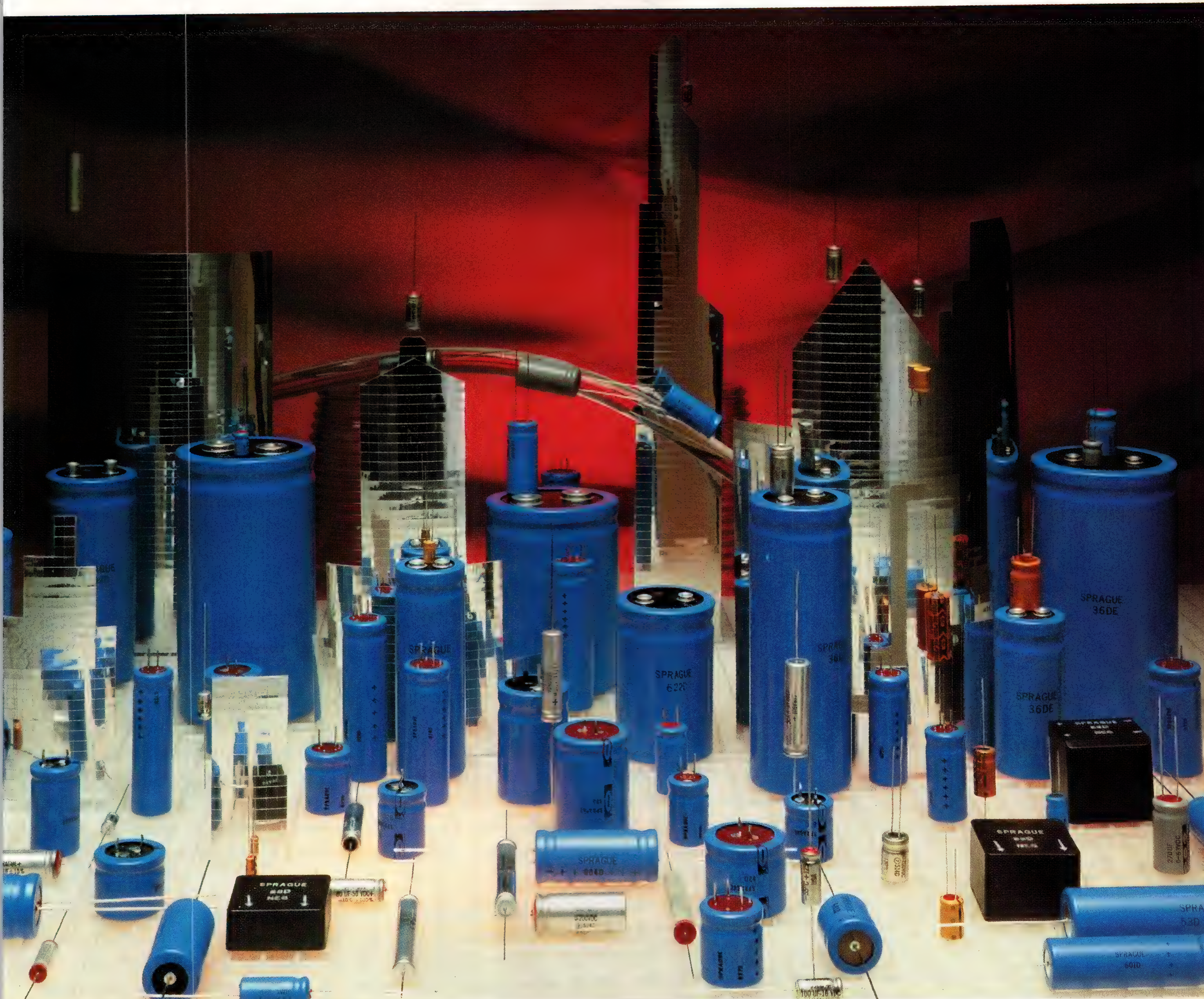

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allow easy upgrades to faster transmission rates.

To meet the Sonet specs, Vitesse Semiconductor developed the VS8010 in a collaborative research agreement with Bell Communications Research. The VS8010 **(Fig 7)** is a GaAs monolithic IC that works with optical drivers and receivers; it contains an 8:1/1:8 multiplexer/demultiplexer, Sonet frame-recovery and -detection circuitry, and the necessary timing generators. The VS8010 operates from Sonet's Synchronous Transport Signal (STS) levels 3 to 24, which encompass line rates from 155.52M to 1.24416G bps.

The VS8010 chip accepts incoming 8-bit parallel data at 155M bytes/sec and sends out a 1.24G-bps serial bit stream. The chip also receives 1.24G-bps serial data and converts it back to byte-wide parallel data. The demultiplexing section of the chip contains the Sonet framing circuitry, which aligns the incoming serial data with the byte boundaries. To ensure proper synchronization and accurate data, the IC transmits and receives the clock signal and the data separately via high-speed, ECL-compatible I/O ports. The VS8010, which uses GaAs enhancement/depletion-MESFET technology, comes in a 52-pin ceramic chip carrier and dissipates about 3W. The device costs $980.

In sum, the trend toward higher data rates and more complex fiber-optic ICs seems clear. Silicon-based chips will continue to perform yeoman service in many complex, low-frequency applications, and GaAs ICs will replace silicon-based devices in telecomm systems that demand faster speeds and higher data rates. Although GaAs fiber-optic ICs are used primarily in long-haul telecommunication links at present, they're already beginning to appear more often in local systems and multichannel video-distribution networks that require very high data bandwidths. **EDN**

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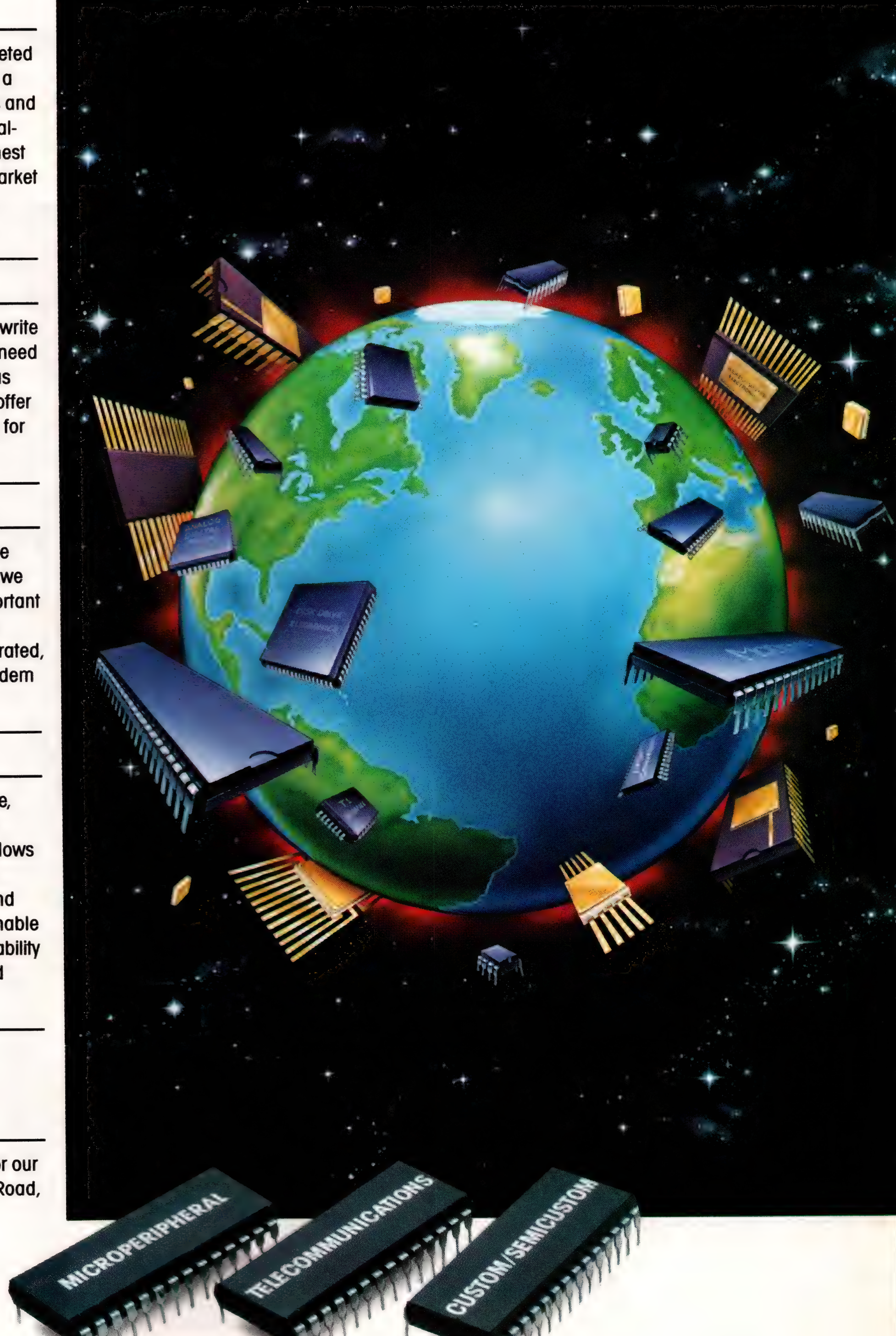

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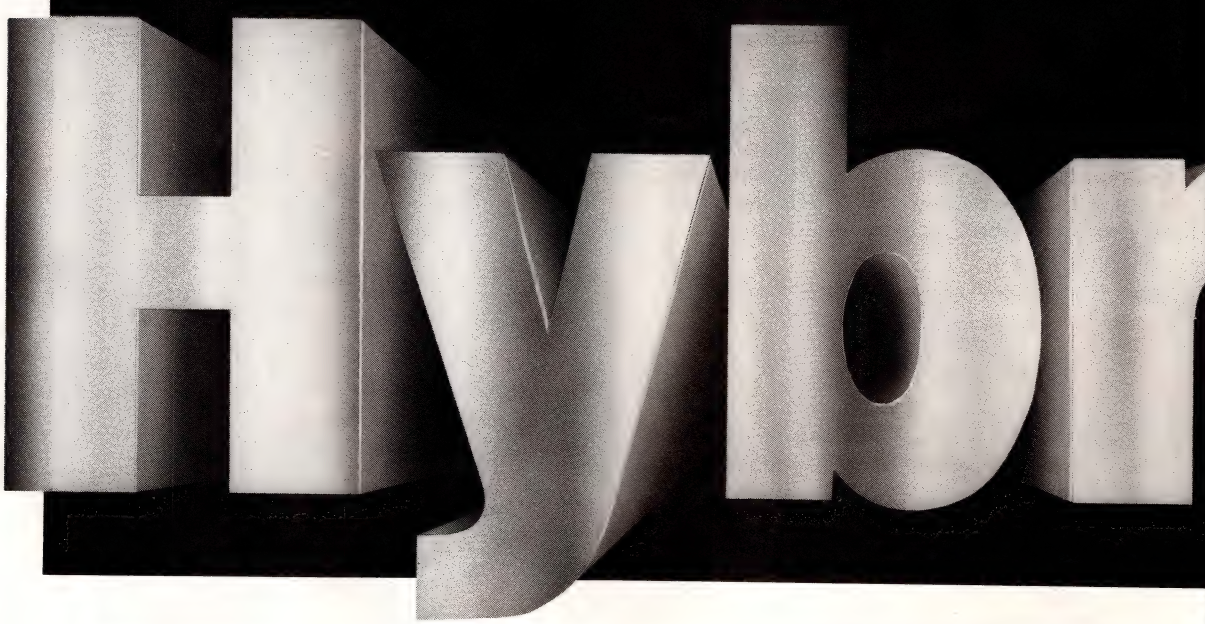

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Inexpensive, shirt-pocket DMMs are smaller and handier than ever

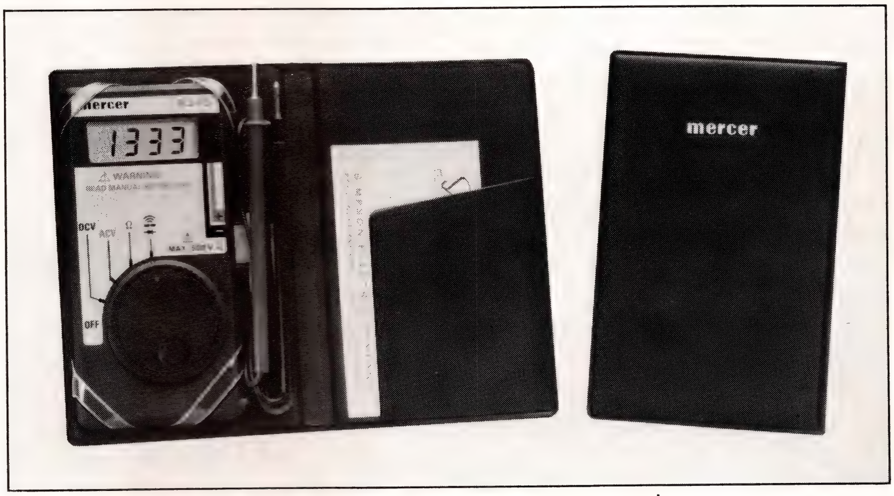
Charles H Small,
Associate Editor

Since their introduction in 1984, low-cost, pocket-size digital multimeters have become increasingly popular with engineers. New models offer more features than their predecessors, and they're handier as well: They're thinner, they have a place for you to stow their leads, and some have a range-hold button that can disable their autoranging function. Many have also replaced the potentially confusing array of pushbuttons with a single control, a dial or switch. Nevertheless, these pocket-size DMMs don't measure up to their somewhat larger cousins—the handheld DMMs—in features, durability, and safety level.

The first pocket-size DMMs to be introduced were probes that incorporated all of the DMM electronics. This early type featured small LCDs for displaying readings and had tiny pushbuttons for selecting functions. Depending from the probe was a small, permanently attached ground lead.

Although many instrument firms offered pocket-size DMMs in 1984, nearly all those DMMs were exactly alike. Most of the firms were importing the same unit from Asia and affixing their private labels to it. Like handheld DMMs, pocket-size DMMs were (and still are) sold primarily through distributors.

Furthermore, the early pocket-size DMMs were significantly smaller and lighter than the industry-standard, handheld models. What's more important, they were significantly less expensive as well: They sold for less than half the price of the least-expensive domestic, handheld DMMs.



Typical of the new breed of wallet-style, pocket-size DMMs *is the Mercer 9345 from Simpson Electric.*

Weighing less than 3 oz, the early pocket-size DMMs could easily reside in an average shirt pocket. By contrast, although most handheld DMMs can fit into a shirt pocket, at 10 oz or more and over an inch thick, they are slightly too big and heavy to be carried routinely in a shirt pocket.

The advanced functions *available on the Soar 3060 include an analog bar graph and a switch for selecting autoranging or manual range selection.*

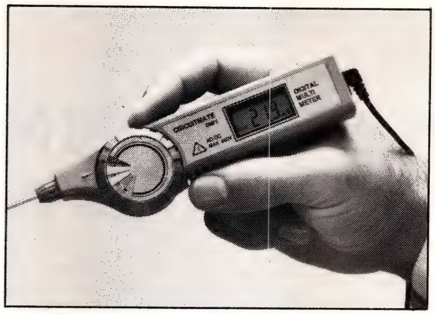
The latest pocket-size-DMM introductions come in two forms: a revised probe-type model and a wallet-style model. Typical of the new probe-type versions is Beckman Industrial Corp's DM71. Selling for $50, the autoranging DM71 has a rotary dial for selecting functions. The rotary dial proves much easier to use than the pushbuttons on the early pocket-size DMMs.

Another new feature is the DM71's data-hold function; it freezes a reading on its 3½-digit display, which is a bit larger physically than its predecessor. On a probe-type pocket-size DMM, a freeze-reading function is essential, because you might have to measure a voltage at a node that's easy to reach but that doesn't let you view the DMM's display simultaneously.

The DM71 bests its predecessors in two other areas: It has a built-in scabbard to house the ground lead, and it runs for 90 hours on a single battery. Older units provided no storage for their ground leads and ran for less than 45 hours on one battery.

The other new configuration, the wallet-style pocket-size DMM, is imported by most major DMM companies. Typical wallet-style models are available from A W Sperry Instruments, B&K Precision, and Simpson Electric. The $34.95 Mercer 9345 from Simpson Electric, for example, measures 2×4¼×⅓ in. and weighs 2 oz. It comes mounted in a small wallet with a Velcro loop for securing the probes. The meter can run for 50 hours on two coin cells. The autoranging unit has a rotary dial for selecting functions and an automatic shut-off function that conserves the battery when the instrument is not in use.

A more advanced wallet-style DMM is available from CG Soar Corp, which is the US representative of Soar Ltd, the Japanese firm that makes most of the pocket-size DMMs that others import and sell under their own labels. The Model 3060, which costs $60, is a 3200-count DMM (that is, the meter displays a higher reading than does a typical 2000-count DMM before autoranging to a higher range).



The latest probe-type DMMs, *such as this Beckman DM71, now feature a rotary dial for selecting ranges instead of the tiny push-buttons employed by earlier versions.*

Along with the usual 3½-digit readout, the 3060 features an analog bar-graph display. It also permits you to disable the autoranging function and select ranges manually, so you can increase the speed of repetitive measurements in the same range. In other words, you don't have to wait for the instrument to select the proper range each time you apply the probes to the nodes under test; you merely select the range once before taking all your measurements. Less-expensive wallet-style DMMs perform autoranging and don't allow manual range selection.

No current measurement

A glance at the front panels of these pocket-size DMMs reveals that they don't provide a current-measurement feature. The front-panel legends also indicate that these instruments can't withstand voltages over 500V.

The pocket-size DMMs' small size accounts for their lack of current measurements and their low standoff-voltage specs: The instruments simply don't have enough room inside their cases for the wide circuit-trace spacing and fuses that high-voltage and current measurements

require. By comparison, handheld DMMs do measure current, and they can withstand voltages as high as 1500V. Thus, they can safely handle jobs that pocket-size DMMs can't.

Neither are pocket-size DMMs as rugged as handheld DMMs. The handheld Model 27 from John Fluke Mfg Co (Everett, WA), for instance, recently demonstrated a 100,000-hour MTBF, which exceeds by a factor of 10 the requirements of MIL-STD-781 and MIL-T-28800. (It sells for $259.) Pocket-size DMMs don't have the rugged, thick, sealed cases and shock-mounted electronics of handheld models such as the Model 27.

Pocket-size DMMs *can* survive drops to hard floors from normal desk heights. But don't put a DMM into your back pocket—if you sit on it, you'll probably break it.

In addition, pocket-size DMMs offer only 0.7% max accuracy, while handheld DMMs offer accuracy of 0.1% or better. Handheld DMMs offer a range of extra features that pocket-size DMMs don't have: 4½-digit displays, transistor checking, decibel measurements, temperature measurements, and true-rms ac measurements are a few examples. Nevertheless, by virtue of their low price and handy size, pocket-size DMMs will continue to be popular with engineers. **EDN**

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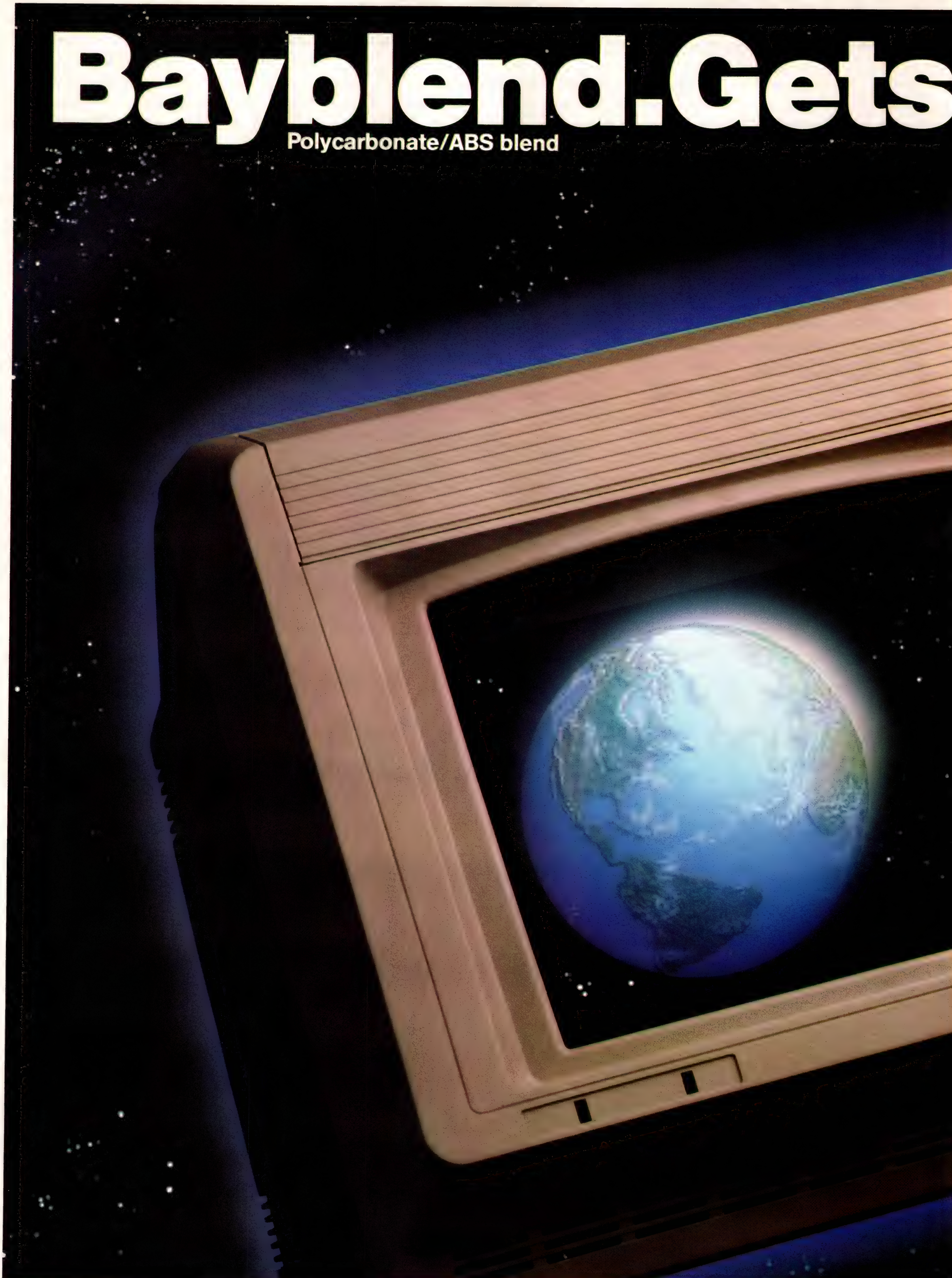
Circle No 740



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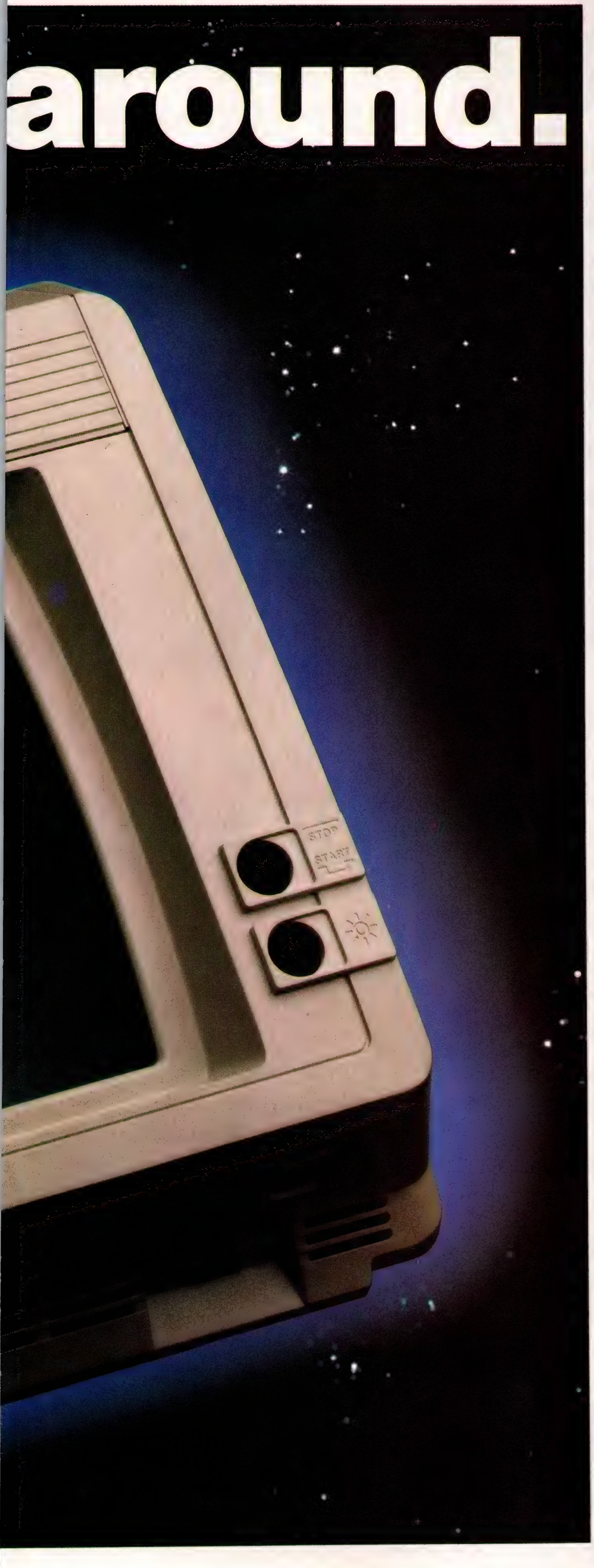

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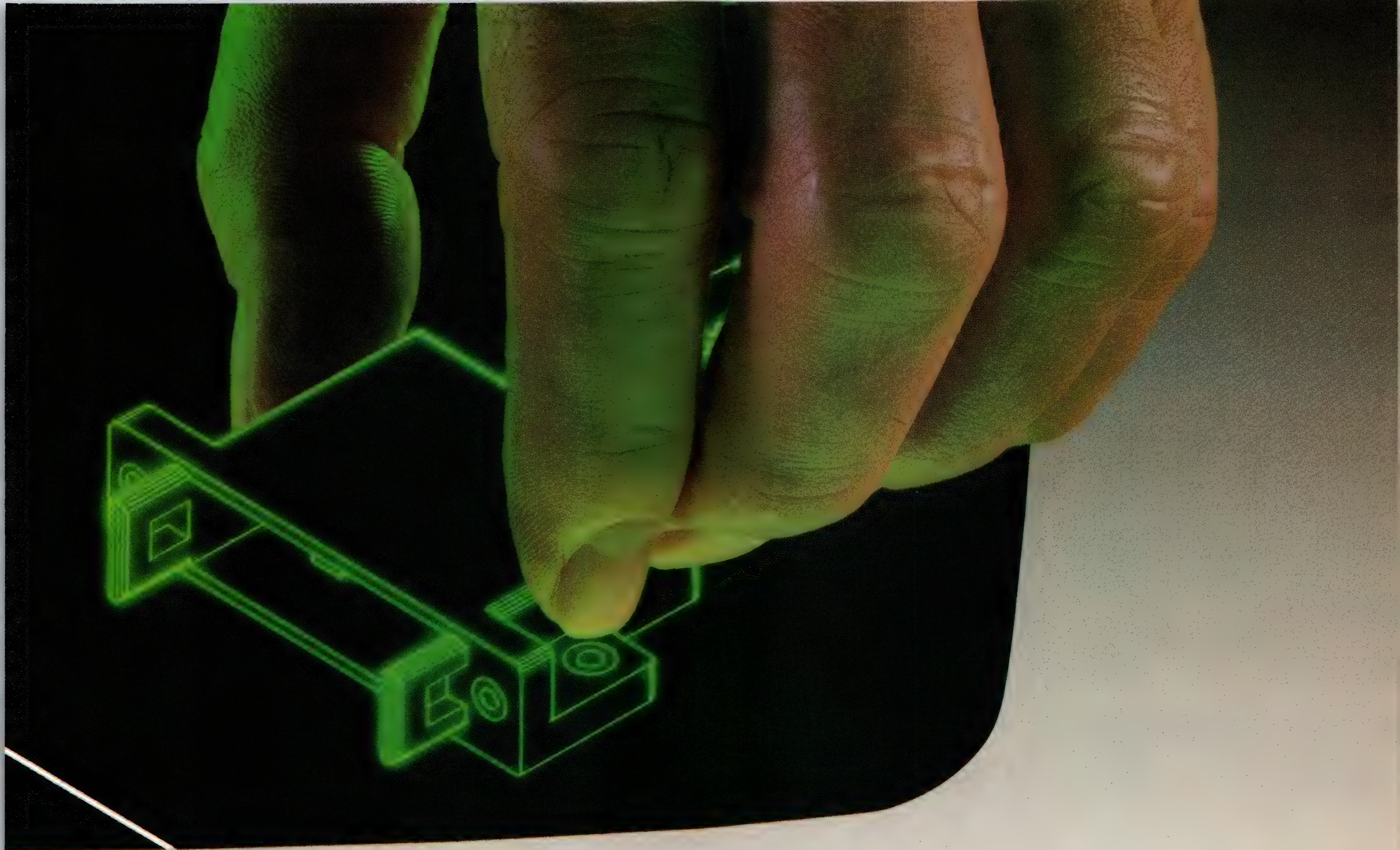

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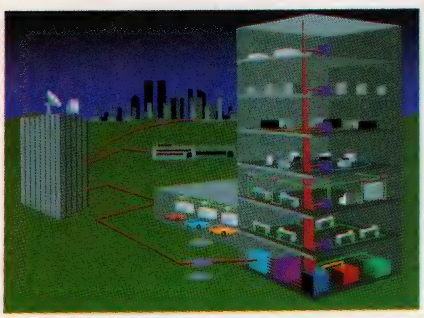

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AMP Interconnecting ideas

CIRCLE NO 88

A New VME Enclosure with Benefits That Really Stack Up:

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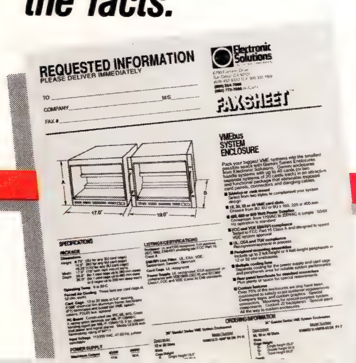

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CIRCLE NO 89

Double-precision, floating-point processor hosts 64-bit data path

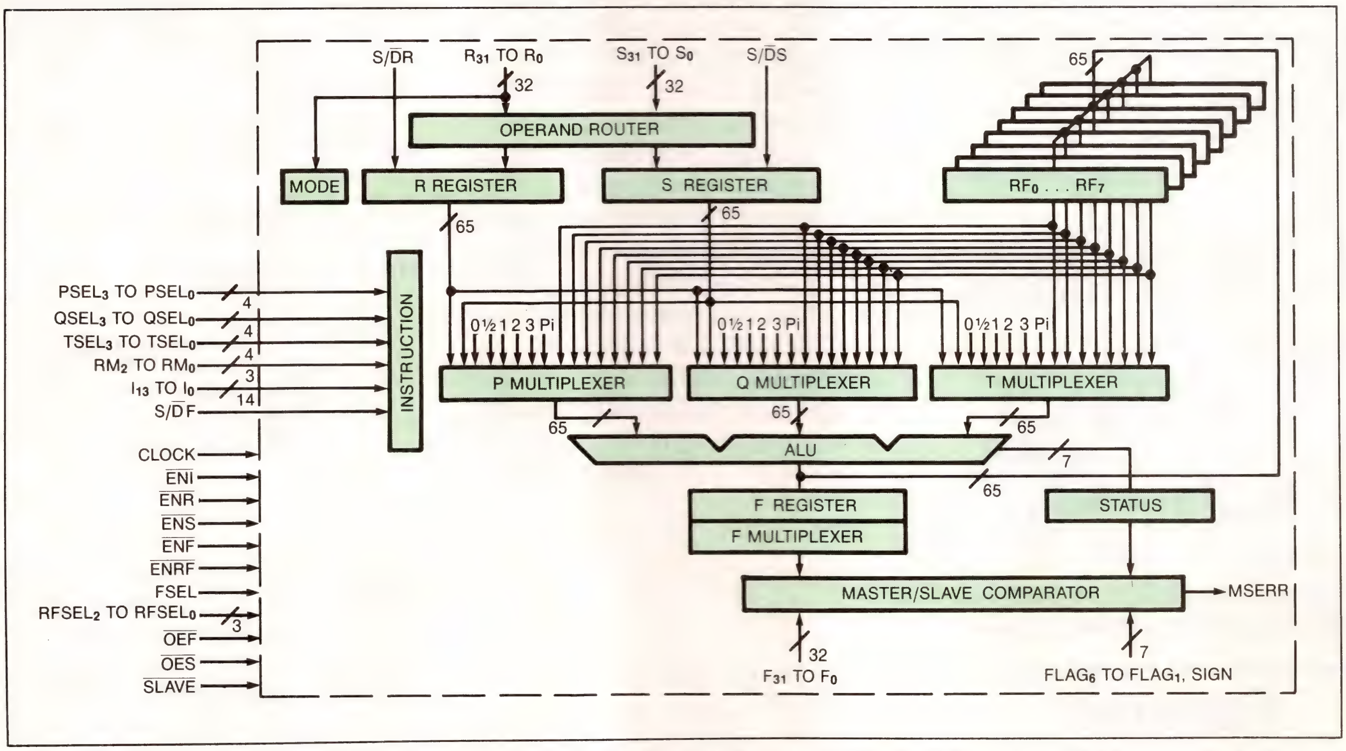
Providing double-precision accuracy for those applications that require extensive number crunching, the Am29C327 floating-point processor also offers a 64-bit data path to facilitate compound operations as well as a 3-input, 64-bit ALU. The 1.2-μm CMOS device provides exact IEEE compliance for denormalized numbers with no degradation in speed, and it complies with seven floating-point standards, including IEEE 754 and IBM System/370.

The ALU has three input ports, which allows it to execute triple-operand functions such as multiply-accumulate and funnel shift, as well as double- and single-operand functions. An output multiplexer can operate at twice the speed of the Am29C327's core, thus allowing the device to output both 32-bit halves of a 64-bit result in one clock cycle.

The chip includes such combinatorial processing elements as a 64×64-bit multiplier and 67-bit adders and shifters. Its register file provides on-chip data storage and consists of eight 65-bit registers with precision tags for all operands. The chip even performs operations for converting an operand from one to another of the seven industry standards to which it complies.

The instruction set includes 35 floating-point instructions, 22 integer instructions, and 1 instruction for moving data. You can use any instruction with either single- or double-precision operands, and you can elect to mix single and double precision within a single operation. The Am29C327 internally performs all operations in double precision, but it permits you to specify the precision of the input and output operands.

The extensive instruction set and the combinatorial processing elements provide single-cycle operation in support of high-level languages and ensure that the end result of a chain of calculations remains accurate at the 32-bit level. Further, the 3-input ALU includes four "sign-change" blocks, each of which you can independently set to invert an operand's sign, pass it unchanged, set it to 0, or set it to 1. This feature lets you superimpose the operations of negation and absolute value on a core operation without reducing the speed of the core operation. Thus, it only takes a single cycle to execute an instruction such as sum of absolute values.



Providing double-precision accuracy, *the Am29C327 64-bit floating-point-processor IC, offers both floating-point and integer instruction sets and performs single-, double-, and mixed-precision operations.*

UPDATE

The Am29C327's 2-stage pipeline registers reside within the ALU. You can select a flow-through mode for scalar applications or a pipelined mode for vector applications. The pipelining determines throughput and latency. In the flow-through mode, the ALU acts as a purely combinatorial device with a throughput yielding an equivalent latency (the delay from the input registers to the output register). In the single-pipelined mode, the ALU contains one pipeline delay for all operations, thereby doubling throughput. For multiplication-accumulation operations, you can select a double-pipelined mode to triple the device's throughput.

The Am29C327 offers a 32-bit and a 64-bit integer format and complies with the following standards: IEEE 32-bit single precision; IEEE 64-bit double precision; 32-bit DEC F; 64-bit DEC D; 64-bit DEC G; IBM 32-bit single precision; and IBM 64-bit double precision. Strict compliance with these standards minimizes the system overhead required for floating-point operations. The chip generates the same result in the IBM mode as would an IBM mainframe; in the DEC mode, it matches its output to that of a VAX.

Mounted in a 169-lead pin-grid array package, the Am29C327 is now available in sample quantities only; volume deliveries are scheduled for the third quarter of this year. A 120-nsec version will sell for $395 (100). A 100-nsec model will cost $595 (100).—***J D Mosley***

Advanced Micro Devices, 901 Thompson Pl, Sunnyvale CA 94088. Phone (408) 732-2400. TLX 346306.

Circle No 719

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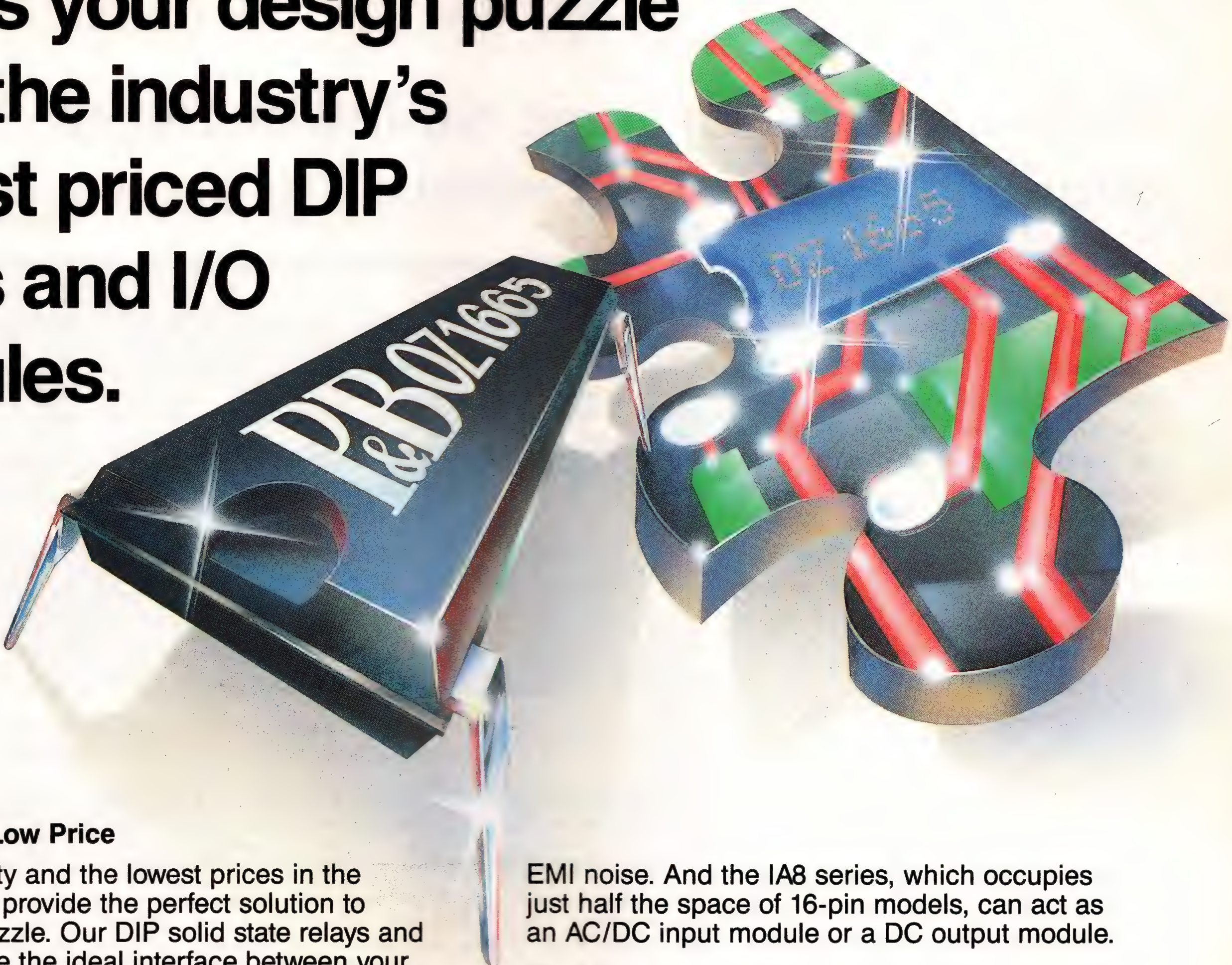

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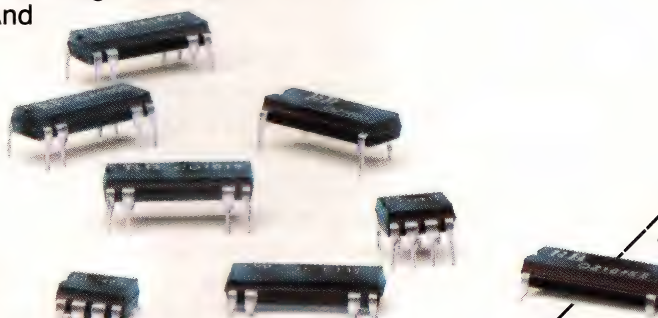

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CIRCLE NO 15

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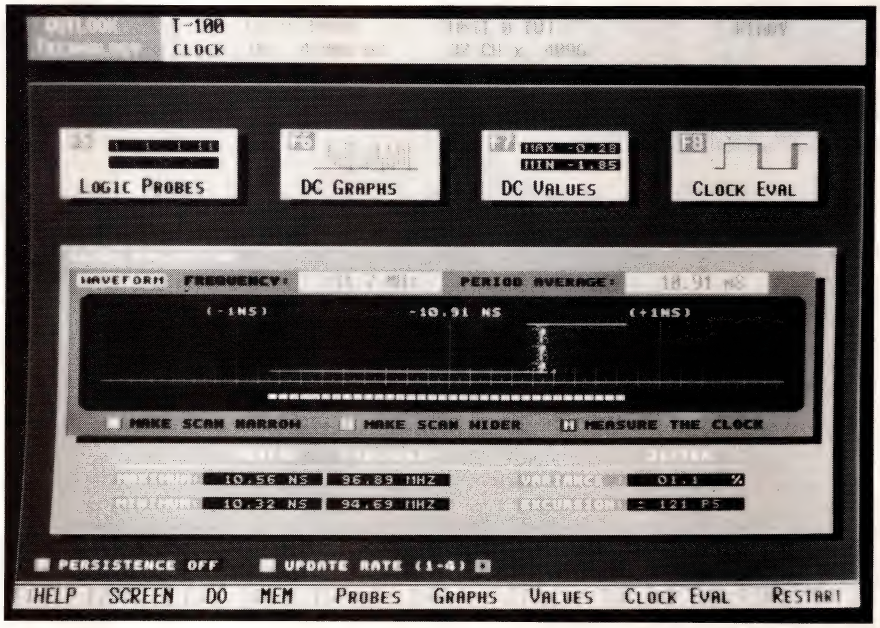
Software tool for logic timing analyzer eliminates setup confusion

Despite the widespread use of logic analyzers for debugging digital hardware, many engineers still find the instruments daunting. With a logic-timing-analysis system that has 160 channels, as does the highest configuration based on the 32-channel, 100-psec-resolution T-100, just getting the probes on the correct circuit nodes can be time consuming. And should you accidentally interchange a pair of probes while attaching them to your circuit, you can waste considerable system-debug time working with logic-analyzer data that doesn't represent what you think it does.

The T-100's new software feature, Logic Probe, addresses the setup problem by providing, via the analyzer's host PC, a series of CRT displays whose contents you can use to verify the accuracy of your setup. By consulting the Logic Probe's displays, you can instantly ascertain activity at the probe tips; the logic-level voltage values; the clock period or frequency; and the degree of jitter exhibited by the clock edges.



This display presents clock information *in graphic and numerical form on the host PC's screen, letting you examine your system's clock during logic-analyzer setup. Similarly informative displays present data about voltage levels and signal activity at the probe tips.*

Each of the displays provides information covering 32 channels. Though some displays present arrays of numerical values—one provides 3-digit representations of the minimum and maximum voltage values at 32 probe tips and at the clock line—others offer data in graphic form.

Some of the graphic presentations mimic a bank of vertically oriented, edgewise, analog panel meters positioned side by side. For example, one graphic display presents a set of vertical bars, each of which indicates the minimum and maximum voltage values measured at a probe tip.

Another display divides the screen into 32 narrow, adjacent rectangles. The top half of each rectangle can display "1" and the bottom half "0." When the analyzer detects logic activity at a probe tip, the 1 and 0 appear alternately in the corresponding rectangle. When you select the analyzer's persistence mode, small check marks appear above the 1 and below the 0, indicating that the signal was briefly in these states.

A clock display resembles what you would see on close examination of a clock edge on a wideband oscilloscope. The clock line's high- and low-voltage levels appear in numerical form by the picture's top and bottom. The horizontal axis denotes time. A vertical bar represents the clock edge. The bar's width denotes the p-p jitter, whereas its density at any point along the time axis represents the portion of the total number of edges occuring at that particular time displacement from the mean value.

The T-100 features several unusual clocking modes, including a 2-GHz equivalent-time sampling mode and a phase-shifted synchronous harmonic mode that allows you to shift the sampling point by 100 psec on successive scans. A multibox feature lets you employ as many as five of the 32-channel units in a high-speed, logic-analysis system. The price of the T-100 ranges from $32,500 to $38,000, depending on the number of input and output probe sets that you order. Software revision 09, which runs on any T-100, contains Logic Probe.

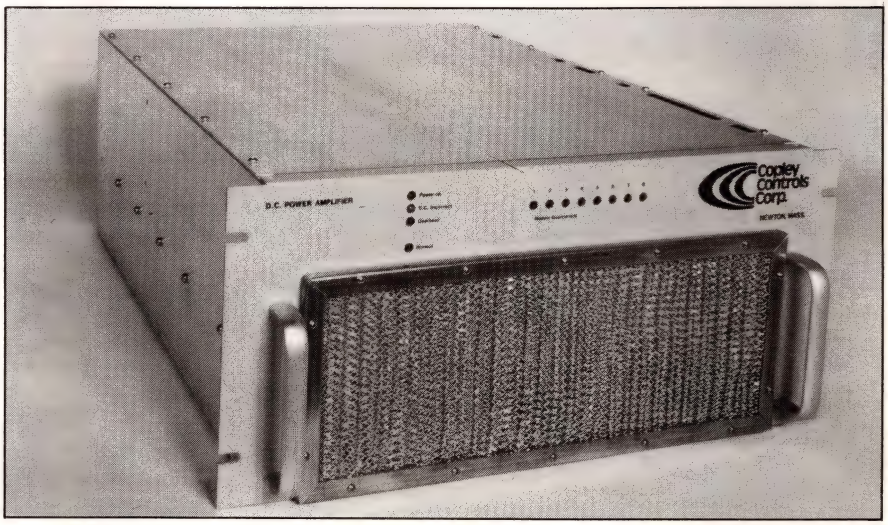
—Dan Strassberg

Outlook Technology Inc, 200 E Hacienda Ave, Campbell, CA 95008. Phone (408) 374-2990. TLX 350479.

Circle No 720

PWM microprocessor-controlled amplifier serves as a voltage or current source

The Model 290, a rack-mountable, pulse-width-modulation power amplifier, provides peak outputs of ±160V at either ±300A for the 290-06 version or ±400A for the 290-08 version over a dc to 3-kHz bandwidth. You can operate each amplifier either as a voltage or current source. The signal-processor board processes the input signal for a particular application and includes a switch for voltage-, current-, or test-mode operation. You can parallel as many as 30 amplifiers in a master-slave configuration to develop ±7000A at ±160V continuous power. The full-load heat dissipation equals 1500W, so efficiency specs at 95%.



Delivering power either as a voltage or as a current source, *the Model 290 PWM amplifier translates 0 to ±10V input signals into 64 kW of dc, ac, or pulsed power.*

The amplifier can achieve full output within 1 msec. The dc stability equals 50 ppm/°C after 30 minutes of warmup. Configured as a voltage source, the Model 290 operates with a load resistance as low as 40 mΩ and delivers sine-wave outputs as high as 25 kVA. The small-signal response measures ±1 dB from dc to 10 kHz and ±2 dB at 15 kHz. The total harmonic distortion (THD) between 20 Hz and 1 kHz equals 2% max for a 25 kVA output. As a current source, Model 290 operates with loads ranging from 50 μH to 50H and with series resistance from 0 to 5Ω. For a 150A rms output, the THD equals 0.2% max at 200 Hz.

The signal-processor board can also configure the amplifier to operate in a test mode. This mode optimizes the amplifier's feedback system for use with a short-circuit load so that the amplifier can be burned in at the factory without having to use a large inductive load. The processor board also contains a series of DIP switches, which optimizes the amplifier frequency response for your specific load and application. These switches are typically set at the factory, but you can program them in the field.

The current-sensing technique uses a resistive shunt and a current-sense preamplifier. In applications involving only a master unit, you can mount these components inside the Model 290. In master-slave systems, you can mount these components externally. The current-sense preamplifier is chopper stabilized for low drift performance and has a 200-kHz bandwidth.

You can adjust the amplifier's transient response from an underdamped to a controlled overshoot level. The power-supply sensitivity is only ±100 μA/V, so the amplifiers will operate with any unregulated supply voltage in a 65 to 165V range.

Each amplifier chassis contains power and filter modules, a power-converter board, and a logic-circuit board, as well as a small front-panel-display board. The power converter provides all the low voltages needed to power the amplifier and operates from the high-voltage power input.

Three brushless dc fans cool the amplifier and receive power from the power converter via a speed controller, which regulates the internal heat sink's temperature at 55°C. When the amplifier is driving a light load, the fans will run slowly and quietly.

Additional Model 290 features include built-in fault detection/protection circuitry, which prevents damage from overvoltage, current overload, or excessive temperature rise; control amplifier operation, which uses external inhibit and enable inputs; and built-in filtering, which holds output noise below 10 mA (10 Hz to 5 kHz) in the current-source mode and below 1 mV (20 Hz to 5 kHz) in the voltage-source mode.

The Model 290 power amplifier weighs 115 lbs, measures 19×8.75×25 in., and costs $18,000. You can expect delivery six weeks ARO.—***Tom Ormond***

Copley Controls Corp, 375 Elliot St, Newton, MA 02164. Phone (617) 965-2410. TLX 285975.

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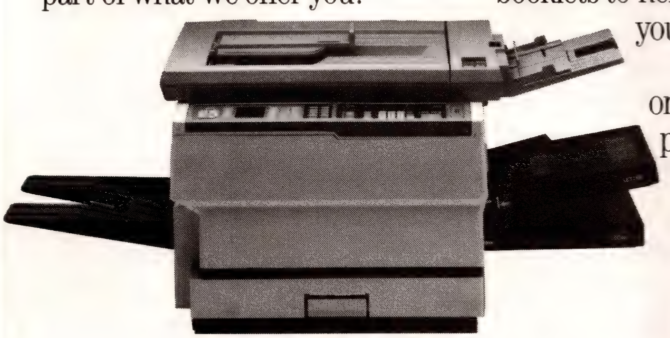

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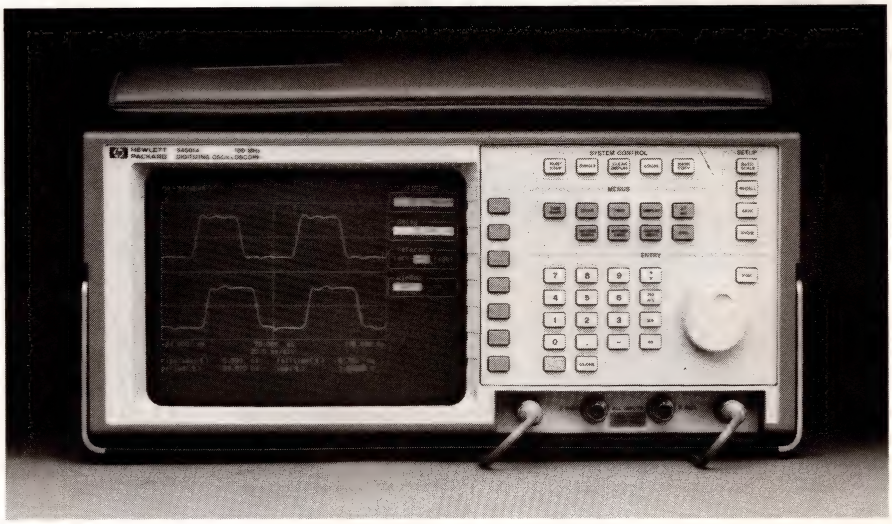
CIRCLE NO 150

$3500 digital storage scope offers four channels and 100-MHz bandwidth



***A combination of dedicated menu keys** plus a soft-key submenu of seven keys simplifies front-panel control of the HP 54501A.*

Priced at $3465, the HP 54501A 4-channel, 100-MHz DSO brings you digital-storage-oscilloscope features at a price substantially closer to that of an analog scope. The 54501A is not a stripped-down version of a high-priced scope: You get an autoscale feature for fast setups, and the scope is capable of automatically measuring such functions as rise and fall times, frequency, period, peak-to-peak voltage, and rms voltage. You also get time and voltage cursors for user-selectable measurements. Because the 54501A has a fully digital timebase, you can make timing measurements that are more accurate than those typical of analog scopes.

In addition, the DSO provides a dual-timebase-windowing feature that performs just like the dual timebase commonly found on high-performance analog scopes. The dual timebase window also includes one feature you won't get on an analog scope—the ability to view pretrigger events.

Besides offering standard edge- and TV-triggering modes, a custom IC inside the 54501A gives you a variety of special triggering functions similar to that of logic analyzers. Pattern triggering, for example, allows you to trigger off the four input channels, selecting either a high, low, or "don't care" pattern.

You can further select the triggering to occur when the last edge enters the specified pattern or when the first edge exits the pattern. You can also use a time-qualified pattern trigger, which can require the pattern you select to exist for a greater or lesser amount of time than the time specified or to satisfy a range of times.

If you want to trigger on synchronous events, you can use any three channels to select high, low, or don't care states, and use the fourth channel as the clock. You can select triggering to occur on the rising or falling edge of the clock when the pattern is either present or not present. You can delay triggering according to the number of events, to as many as 16 million events, or you can delay it according to time increments ranging from 30 nsec to 160 msec.

Display options allow the selection of various levels of display persistence, including infinite persistence, which is useful when examining waveform jitter and noise. Alternatively, you can use waveform averaging to eliminate noncorrelated noise.

You can save and recall waveforms as well as oscilloscope setups. The 54501A has four nonvolatile waveform memories and two volatile pixel memories. With two 10M-sample/sec, 8-bit ADCs, the digital storage oscilloscope, like a nonstorage analog scope, is intended primarily for repetitive waveform applications. You can, however, use it to capture single-event waveforms to about 1 MHz. As with all DSOs, repetitive events that have a long period between trigger events present no problem. The display always remains bright, and you never need a scope hood.

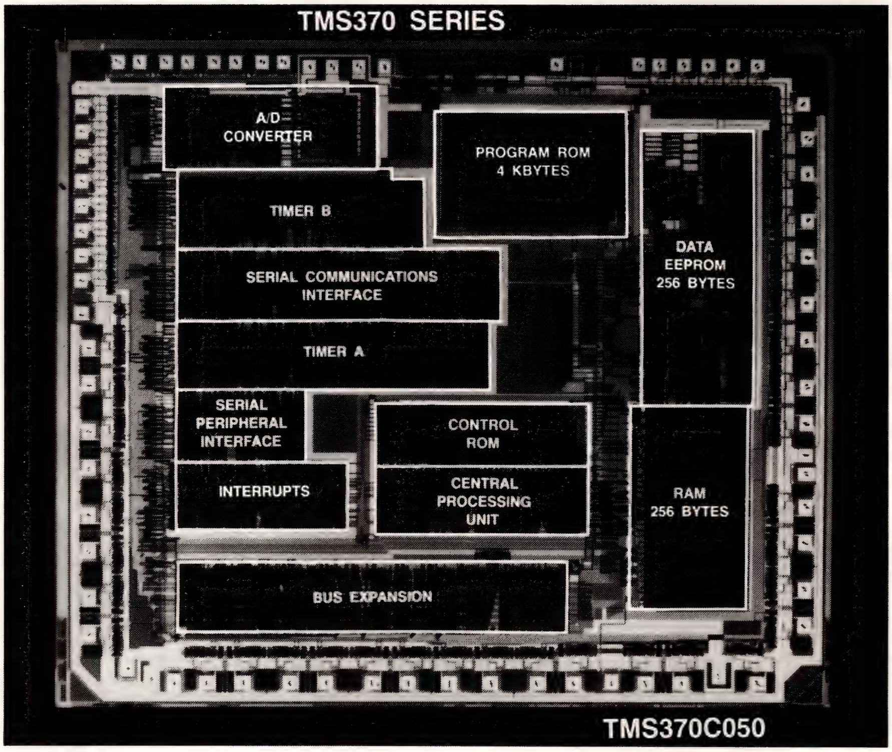
The 54501A comes with a standard IEEE-488 interface that comprises both a talker and a listener interface. The scope connects directly to IEEE-488-compatible printers for hard-copy output. For computer-aided testing, you can also load test-template waveforms over the IEEE-488 bus via a controller. The 54501A can perform more than 10 waveform acquisitions and IEEE-488 waveform transfers each second.

Thanks to its weight of 22 lbs, the DSO is suitable for applications requiring portability.—***Doug Conner***

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone local office.

Circle No 722

Configurable 8-bit μC family includes in-circuit emulation system



The TMS370 family of 8-bit μCs *allows you to mix and match modules to meet your design goals. You can then configure the TMS370 XDS in-circuit emulator to develop your code before you've even ordered the device.*

Today's electronic marketplace puts tremendous emphasis on getting to market quickly, yet stresses the importance of keeping costs down and designs proprietary. The TMS370 family of 8-bit μCs offers you the convenience of configuring a semicustom μC from a list of available modules. Moreover, while the chip is being created, you can use the family's XDS in-circuit emulator to complete the final testing of the software and the rest of your system.

The TMS370 family is based on a modular design methodology that uses a common internal bus to interconnect individual modules. Besides the six standard parts available to choose from, you have the option of deciding which modules you want your μC to include. At present, the list of modules available consists of mask-programmable ROM, static RAM, EPROM, EEPROM (for data and program memory), serial I/O, timers, digital I/O, and 8-bit A/D converters.

You also have the option of a configurable in-circuit emulator. The TMS370 XDS has an expansion board as well as an emulator board. The expansion board allows you to create a custom version of an 8-bit μC by providing various modules that you can use as if they were on the μC. The expansion board also includes a prototype area where you can test your own custom modules.

Once you've checked out the software with the XDS, you can elect to use one of the two available Form Factor Emulators (FFEs), the TMS370C810 or the TMS370C850. These prototyping μCs have the same size, shape, and function as available ROM versions, but have EEPROM in place of the ROM. Using an FFE, you can evaluate the system in terms of your target application.

Although there are only six standard parts available at this time, you can expect more later this year. The TMS370C010 and 310 both include 4k bytes of ROM, 128 bytes of RAM, a serial peripheral interface, a timer, and 22 I/O pins. The TMS370C010 has 256 bytes of EEPROM, though, and the 310 has none. The TMS370C810 FFE is just like the 010 except that its 4k-byte EEPROM takes the place of the ROM.

The TMS370C050 and 350 each have 4k bytes of ROM, 256 bytes of RAM, an 8-bit A/D converter, a serial communications interface, a serial peripheral interface, a timer, 55 I/O pins, and an expansion bus. The expansion bus allows the CPU to access external devices as if they were on chip. The TMS370C850 FFE is identical to the 050 except that its 4k-byte EEPROM substitutes for the 050's 4k-byte ROM.

All members of the family are fabricated in a 1.6-μm CMOS process. The TMS370C010 and 310 devices are available in 28-pin plastic DIPs or PLCCs (plastic leaded chip carriers) and cost \$3 to \$7. The TMS370C050 and 350 come in 68-pin PLCCs and cost between \$4.50 and \$10. Each family member runs off a 5V supply over the temperature range of −40 to +85°C.

—David Shear

Texas Instruments Inc, Semiconductor Group, Box 809066, Dallas, TX 75380. Phone (800) 232-3200.

Circle No 723

How To Wring Workstation-Level PCB Designs Out Of Your PC.

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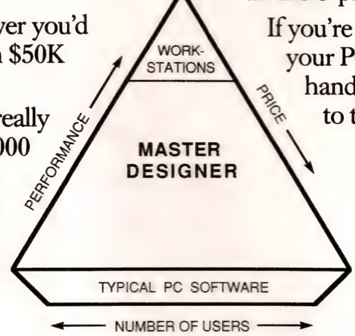

For forward annotation of logic changes and "history independent" back annotation, Master Designer also has an ECO processing option.

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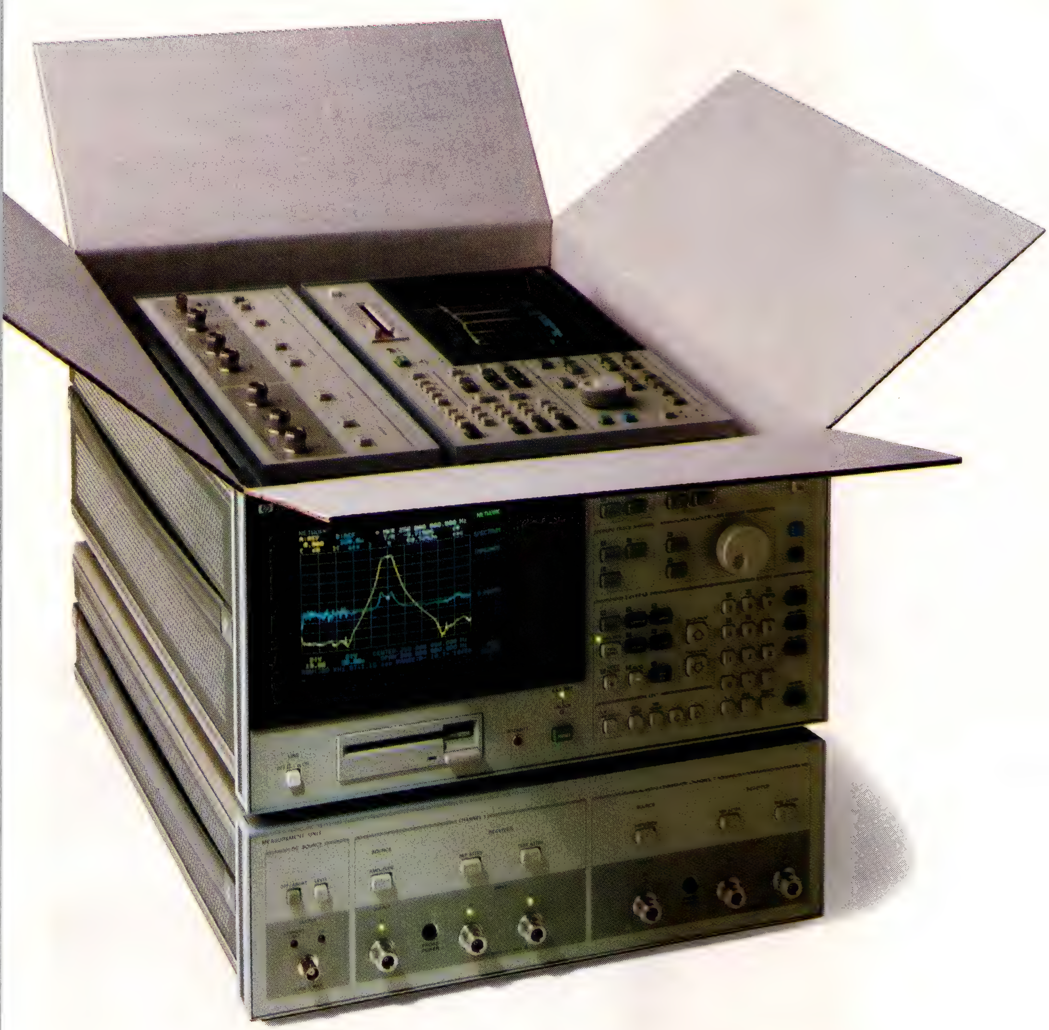

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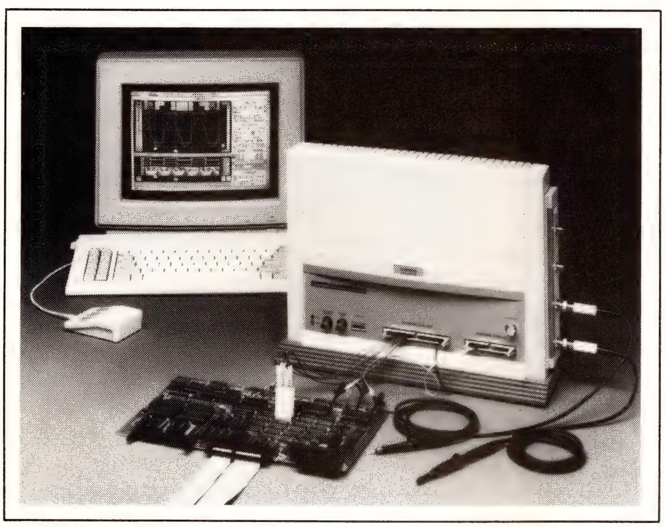
READERS' CHOICE

Of all the new products covered in EDN's **March 17, 1988,** issue, the ones reprinted here generated the most reader requests for additional information. If you missed them the first time, find out what makes them special: Just circle the appropriate numbers on the Information Retrieval Service card, use EDN's Express Request service, or refer to the indicated pages in our **March 17, 1988,** issue.

▲ LAPTOP COMPUTER

The LP-286 laptop computer is compatible with the IBM PC/AT. It features an 80C286 μP that runs at 6 or 12 MHz with an 80287 coprocessor option (pg 215).
Dauphin
Circle No 502

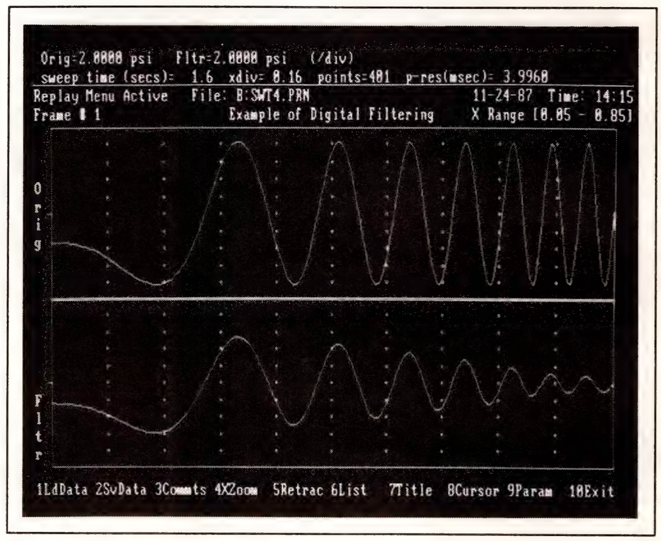


▲ INSTRUMENT

The Omnilab 9240 combines a full-function 100-MHz digital storage oscilloscope with a 48-channel logic analyzer (pg 99).
Orion Instruments Inc
Circle No 501

NTSC FIELD BUFFER

The μPD42270C field buffer IC can be used in digital TV applications and in applications such as teletext system monitoring, broadcast video, and medical imaging (pg 230).
NEC Electronics Inc
Circle No 503



▲ DIGITAL FILTERING

Snap-Filter digital filtering program provides four types of filter: lowpass, highpass, bandpass, and band-reject (pg 242).
HEM Data Corp
Circle No 505

PRESSURE SENSOR

The NPS Series pressure sensor is packaged in plastic lead frames and features two pressure ports that are compatible with 1⁄16-in. plastic tubing (pg 234).
NovaSensor
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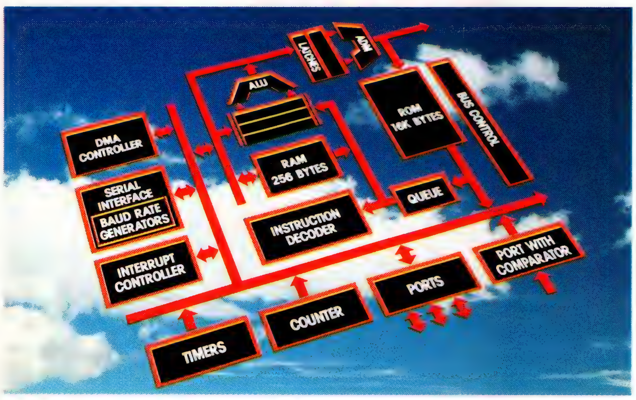

Offering higher integration, higher speed and enhanced functionality, the V25 meets more of your design needs. Which is why so many innovative designers are choosing the V25 for their 16-bit micro-based systems.

- □ High integration: programmable interrupt controller; 2-channel serial I/O port; three 16-bit timers; time-base counter and more.
- □ High speed: 16/32-bit temporary register/shifter; 16-bit loop counter and prefetch pointer.
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- □ Two stand-by modes: halt and stop.

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NEC has just launched UV EPROMs into the 2M-bit era. The new μPD27C2001D gives you 2M-bit capacity in a 256K x 8 organization. High integration is complemented by high speed. With access times as fast as 150ns, our 2M-bit devices eliminate wait states for your CPU. Programming is also fast at 100μs per byte. The 4-byte page write mode multiplies programming speed.

- □ Organization: 256K x 8.
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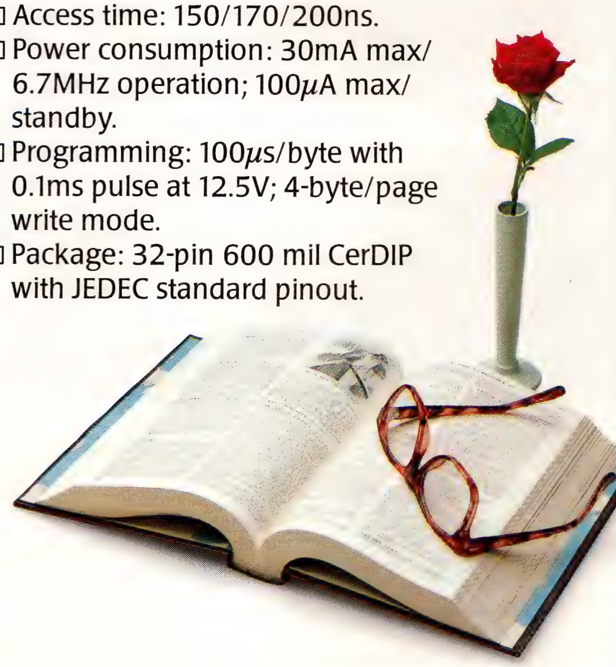
- □ Power consumption: 30mA max/ 6.7MHz operation; 100μA max/ standby.
- □ Programming: 100μs/byte with 0.1ms pulse at 12.5V; 4-byte/page write mode.
- □ Package: 32-pin 600 mil CerDIP with JEDEC standard pinout.



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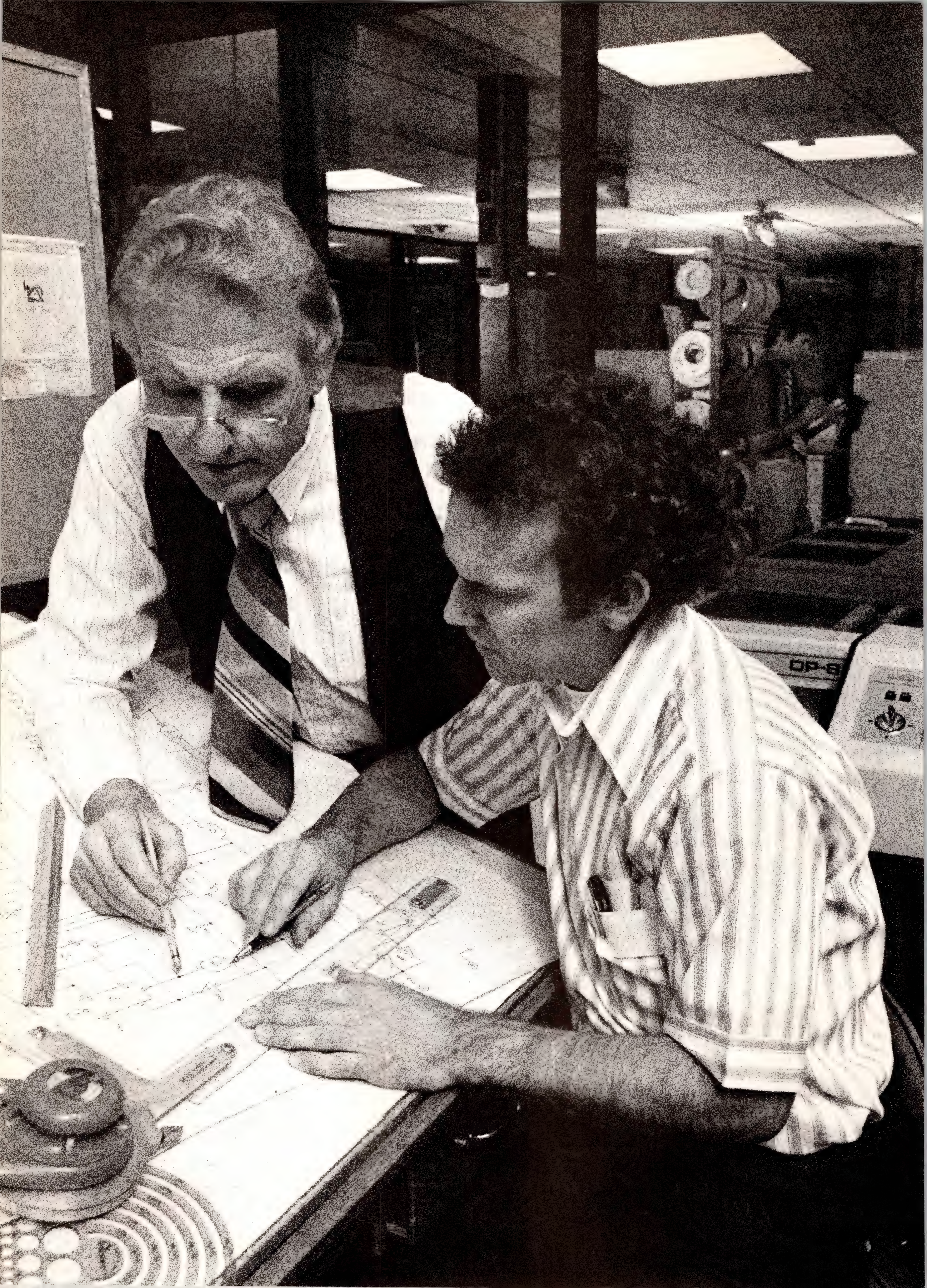

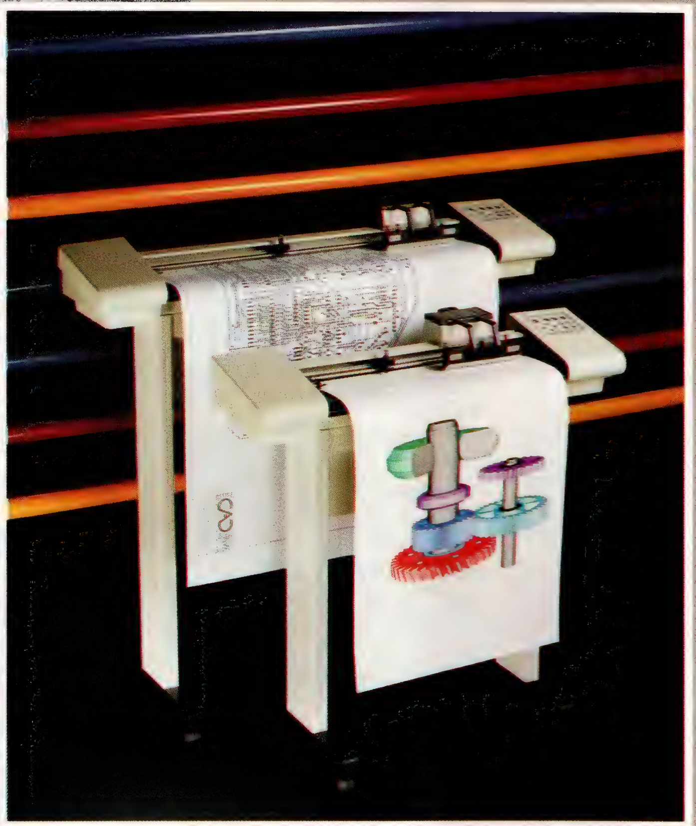

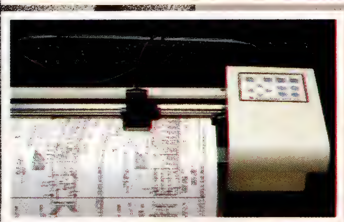

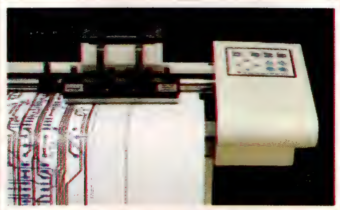

LEADTIME INDEX

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
TRANSFORMERS								
Toroidal	10	0	60	30	0	0	9.6	9.7
Pot-Core	11	0	67	22	0	0	8.8	10
Laminate (power)	12	29	29	24	6	0	8.3	9.6
CONNECTORS								
Military panel	0	33	67	0	0	0	6.0	10.4
Flat/Cable	8	23	46	8	15	0	9.3	4.7
Multi-pin circular	8	23	46	8	15	0	9.3	11.6
PC (2-piece)	0	46	54	0	0	0	5.2	7.2
RF/Coaxial	12	47	41	0	0	0	4.2	5.2
Socket	15	55	30	0	0	0	3.5	3.7
Terminal blocks	10	52	33	5	0	0	4.4	5.7
Edge card	6	50	44	0	0	0	4.5	5.8
D-Subminiature	24	47	29	0	0	0	3.2	4.4
Rack & panel	0	58	33	9	0	0	5.2	6.4
Power	21	43	36	0	0	0	3.7	5.4
PRINTED CIRCUIT BOARDS								
Single sided	5	43	47	5	0	0	5.4	3.7
Double sided	4	39	53	4	0	0	5.6	6.5
Multi-layer	0	15	80	5	0	0	7.4	7.8
Prototype	4	79	13	4	0	0	3.2	5.4
RESISTORS								
Carbon film	41	31	24	4	0	0	3.1	2.7
Carbon composition	32	23	31	14	0	0	5.1	4.3
Metal film	41	19	33	7	0	0	4.1	4.1
Metal oxide	29	14	28	29	0	0	7.1	4.0
Wirewound	12	36	40	12	0	0	5.8	6.5
Potentiometers	15	36	26	19	4	0	6.8	5.2
Networks	36	23	32	9	0	0	4.4	5.7
FUSES	50	13	33	4	0	0	3.5	2.9
SWITCHES								
Pushbutton	13	41	33	13	0	0	5.5	4.6
Rotary	5	30	45	20	0	0	7.4	5.4
Rocker	10	40	30	20	0	0	6.4	5.4
Thumbwheel	19	25	25	25	6	0	8.0	9.4
Snap action	13	40	33	14	0	0	5.6	6.7
Momentary	13	47	27	13	0	0	5.1	5.9
Dual-in-line	8	54	23	15	0	0	5.3	6.1
WIRE AND CABLE								
Coaxial	25	50	15	10	0	0	3.8	3.6
Flat ribbon	36	36	23	5	0	0	3.3	3.1
Multiconductor	32	47	16	5	0	0	3.0	4.1
Hookup	46	32	18	4	0	0	2.7	2.8
Wirewrap	47	23	24	6	0	0	3.3	2.8
Power cords	30	29	26	15	0	0	5.0	3.1
POWER SUPPLIES								
Switcher	0	46	31	23	0	0	7.0	7.9
Linear	6	39	44	11	0	0	6.0	8.6
CIRCUIT BREAKERS	11	33	33	23	0	0	6.9	8.7
HEAT SINKS	14	41	27	18	0	0	5.8	5.3
BATTERIES								
Lithium coin cells	7	53	33	7	0	0	4.8	—
9V alkaline	47	20	20	13	0	0	4.1	—
Real-time clock back-up	10	40	40	10	0	0	5.6	—
RELAYS								
General purpose	20	40	25	15	0	0	5.2	6.1
PC board	9	32	27	27	5	0	8.4	8.5

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
Dry reed	0	23	46	31	0	0	9.1	11.8
Mercury	0	13	74	13	0	0	8.2	10.7
Solid state	11	39	28	22	0	0	6.5	10.8
DISCRETE SEMICONDUCTORS								
Diode	28	24	21	21	7	0	7.2	7.0
Zener	22	19	22	29	4	4	9.0	9.2
Thyristor	16	16	31	32	0	5	9.4	8.5
Small signal transistor	14	14	31	27	9	5	10.9	6.9
MOSFET	25	13	31	25	0	6	8.6	7.9
Power, bipolar	21	29	21	29	0	0	6.9	8.3
INTEGRATED CIRCUITS, DIGITAL								
Advanced CMOS	6	22	39	33	0	0	8.8	9.5
CMOS	9	23	27	36	0	5	9.9	7.7
TTL	16	26	32	21	5	0	7.7	5.9
LS	17	22	33	22	0	6	8.4	6.1
INTEGRATED CIRCUITS, LINEAR								
Communication/Circuit	0	42	33	25	0	0	7.4	5.6
OP amplifier	5	35	30	25	0	5	8.6	6.4
Voltage regulator	9	41	27	18	0	5	7.4	6.4
MEMORY CIRCUITS								
DRAM 16K	0	23	23	38	0	16	13.3	7.7
DRAM 64K	0	19	25	37	6	13	13.8	10.4
DRAM 256K	0	6	25	37	13	19	17.3	15.8
DRAM 1M-bit	0	1	0	58	8	33	21.6	17.5
SRAM 4K × 4	0	10	30	40	20	0	14.2	—
SRAM 8K × 8	0	0	15	62	23	01	17.1	—
SRAM 2K × 8	0	18	9	45	18	91	15.9	—
ROM/PROM	11	23	44	22	0	0	7.5	10.3
EPROM 64K	8	23	23	38	0	8	10.8	10.3
EPROM 256K	0	21	29	43	0	7	11.7	9.3
EPROM 1M-bit	0	14	29	43	0	14	13.8	19.4
EEPROM 16K	11	1	44	33	11	0	11.6	13.2
EEPROM 64K	0	18	36	36	0	10	12.1	11.5
DISPLAYS								
Panel meters	9	28	27	36	0	0	8.4	5.8
Fluorescent	15	31	0	46	0	8	10.4	7.8
Incandescent	25	25	17	33	0	0	7.1	5.4
LED	19	33	33	15	0	0	5.7	5.3
Liquid crystal	8	17	33	33	0	9	11.0	8.4
MICROPROCESSOR ICs								
8-bit	7	27	27	39	0	0	8.9	6.6
16-bit	9	28	27	36	0	0	8.4	7.3
32-bit	0	21	36	36	7	0	10.8	9.8
FUNCTION PACKAGES								
Amplifier	11	23	22	44	0	0	9.2	9.3
Converter, analog to digital	0	19	36	45	0	0	10.4	9.8
Converter, digital to analog	0	19	36	45	0	0	10.4	9.2
LINE FILTERS	8	53	8	31	0	0	6.6	6.0
CAPACITORS								
Ceramic monolithic	17	33	29	21	0	0	6.3	4.7
Ceramic disc	9	39	22	30	0	0	7.3	5.8
Film	14	24	24	38	0	0	8.4	5.7
Aluminum electrolytic	8	36	12	44	0	0	8.7	6.5
Tantalum	14	27	32	27	0	0	7.4	7.1
INDUCTORS	5	37	32	26	0	0	7.4	6.8

Source: Electronics Purchasing Magazine's survey of buyers.

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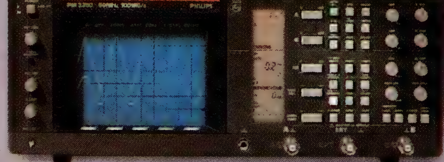

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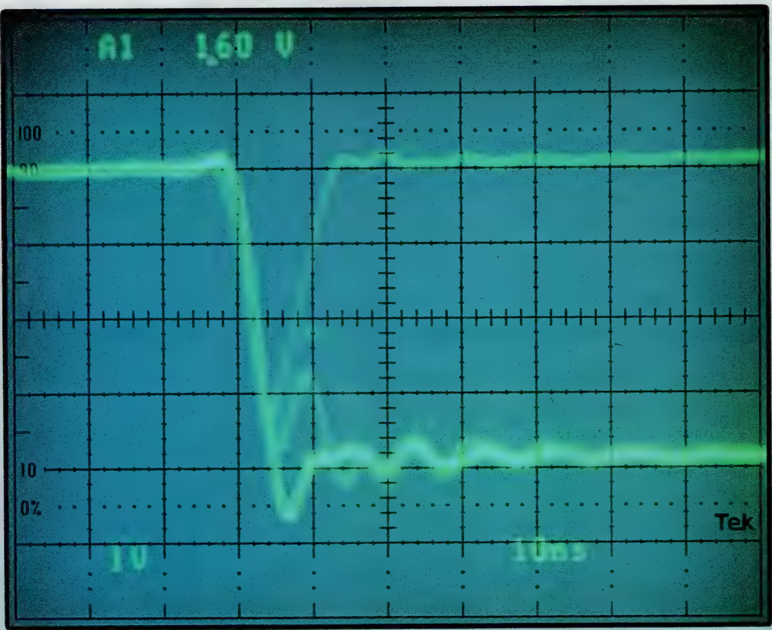

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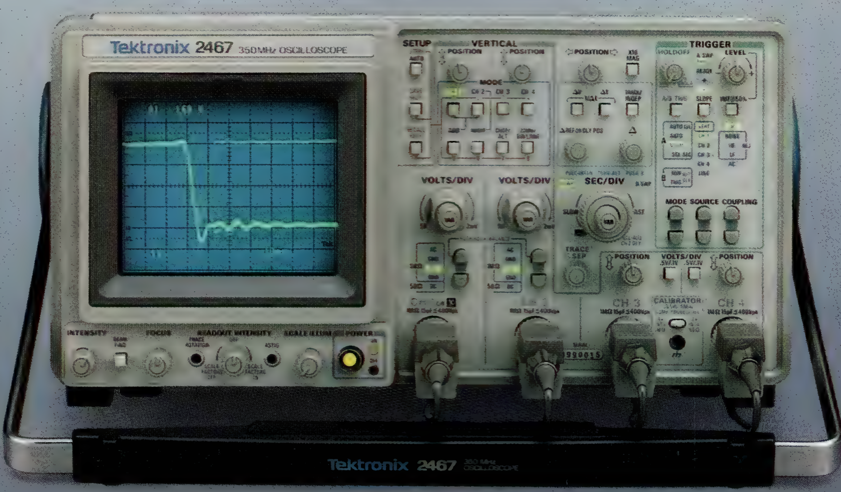

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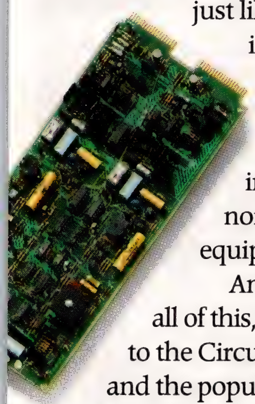

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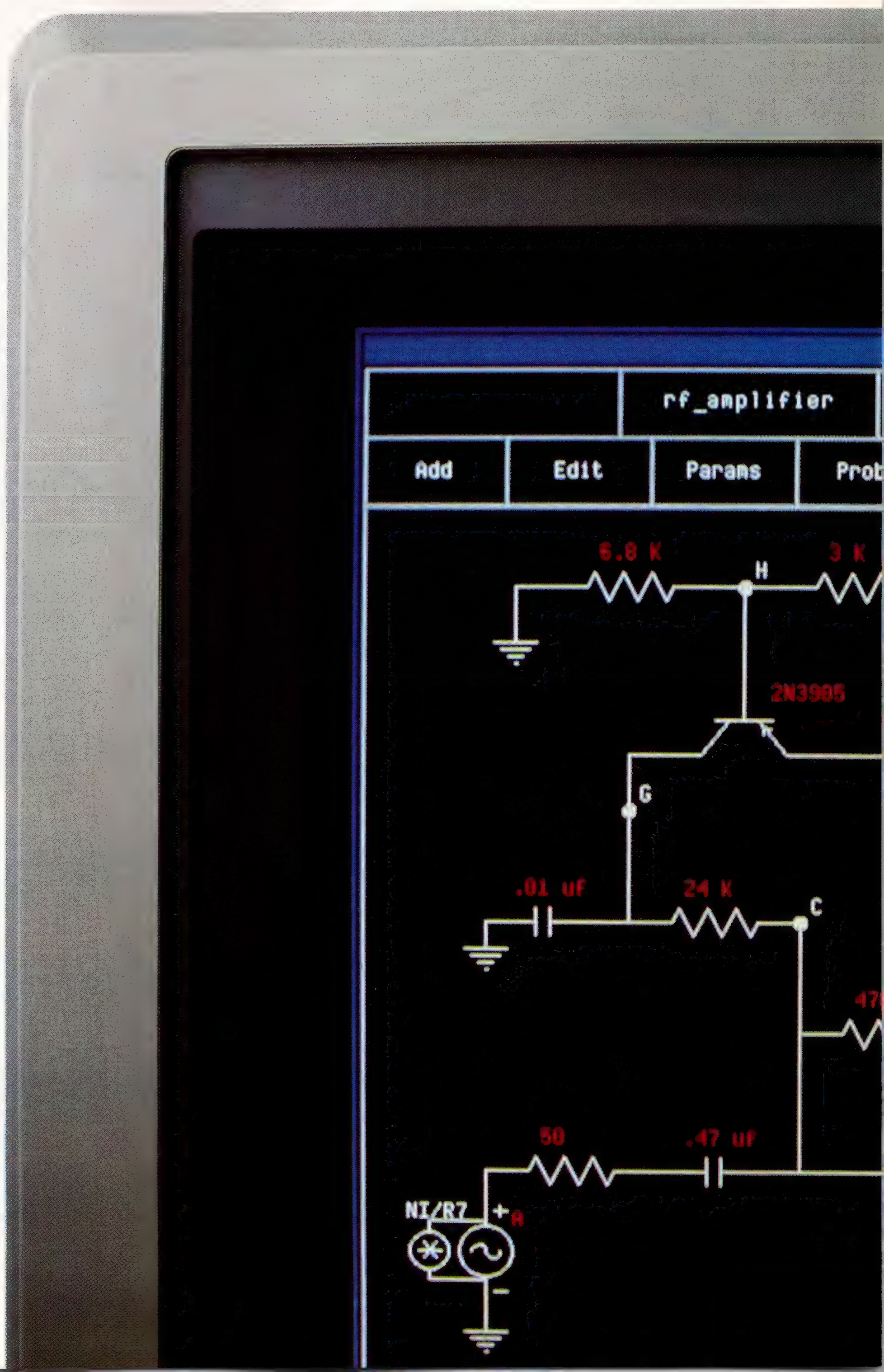


Special Report

Graphic programming languages provide an intuitive *and unconventional approach to controlling instrumentation. (Photo courtesy National Instruments)*

Laboratory-automation software

The time-honored tradition of recording, analyzing, and charting experimental data at the lab bench may take maximum advantage of the company coffee pot, but it destroys an engineer's productivity. Fortunately, software can automate these tedious chores, shifting them to that patient engineering assistant—the personal computer.

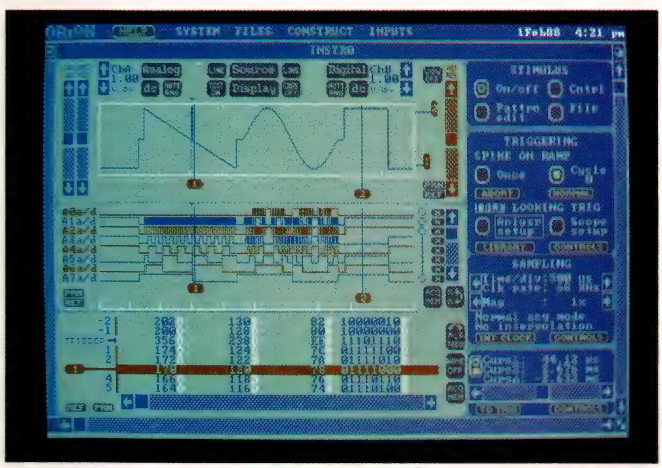
Steven H Leibson, *Regional Editor*

Today's truly low-cost personal computers (PCs), coupled with instrumentation specifically designed to allow computer control, greatly enhance your ability to create automated test systems. PC-based software packages that make your data-acquisition job much easier are now plentiful. Further, many of these products also take advantage of the PCs' extensive floating-point math and excellent graphics capabilities to automate data analysis and presentation.

Experimental research comprises three basic tasks: data acquisition, data analysis, and data presentation **(Fig 1)**. Automating these tasks eliminates human error and gives you better tools for analyzing and presenting data. Unfortunately, it's not as easy to classify the software that performs these tasks. You can find products that perform one, two, or all three of these tasks, and some that perform only part of one task.

When you're evaluating laboratory-automation software, suggests Keithley Instruments **(Ref 1)**, you should use three selection criteria: ease of use, adaptability, and processing speed. You'll also want to consider at least one other factor—cost. The prices for laboratory-automation software packages range from nothing (the vendor supplies the software for free when you purchase the instrument) to several thousand dollars.

For the data-acquisition portion of the job, vendors offer I/O drivers and libraries that augment general-purpose programming languages with data-acquisition and -analysis extensions, versions of popular programming languages especially tailored for data-acquisition applications, all-new programming languages specifically intended for automating the laboratory, engineering-oriented spreadsheet packages, and menu-driven programs that do all three tasks for you without any programming whatsoever. The right software package for you will be the product that convinces your computer and instrumentation to take the measurements you



***Software that comes with** the Omnilab 9240 from Orion Instruments can display time-aligned waveforms from the instrument's digital-storage-oscilloscope and logic-analyzer sections. In addition, the software can store these waveforms on a PC's disk for subsequent analysis.*

Unfortunately, you can't easily classify laboratory-automation software packages.

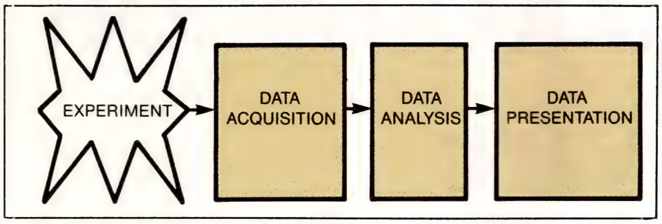


Fig 1—Laboratory-automation software performs three basic tasks: *acquisition, analysis, and presentation. Vendors of PC software offer packages that perform one, two, or all three tasks, but because no standard data format exists, you must take care to select compatible software when mixing products from different vendors.*

want, at a price you can afford.

Many vendors of PC-based instrumentation bundle data-acquisition software with the bus-specific instruments they sell. For example, Heath/Zenith supplies a menu-driven software package with its 20M-sample/sec SDS-5000, a dual-channel, digital-storage-oscilloscope (DSO) card that plugs into the IBM PC or PC/AT bus and costs $1995. The software package employs a menu system similar to the one created by Lotus Development Corp for its ubiquitous Lotus 1-2-3 spreadsheet package.

By using menu selections, you can configure, control, and operate as many as four SDS-5000 card sets concurrently. The software can display eight digitized waveforms on the PC's screen at once. It can also do some analysis of the captured data: It can perform waveform math (addition and subtraction), waveform comparison, smoothing, and signal averaging. In addition, you can save the digitized information on the PC's disk in ASCII format for subsequent analysis by another vendor's software package.

Similarly, Orion Instruments provides a comprehensive software package along with its PC-based $8900 Omnilab 9240, which combines the features of a dual-channel, 100M-sample/sec DSO; a 200-MHz logic analyzer; an analog-stimulus generator; and a 24-bit digital-stimulus generator. The product's software provides time-correlated displays of sampled analog and timing waveforms and a logic-state table on the PC's screen. The software also allows you to set up a sophisticated trigger based on a combination of the sampled analog and digital signals. You control the Omnilab with your PC by using a special adapter card that plugs into an IBM PC/AT-compatible bus.

Omnilab's software can also store the captured information in a disk file for subsequent editing and display. You can use the PC's standard screen-dump routines to obtain a printout of the waveforms. Although the software currently stores waveforms on the PC's disk in a proprietary format, the company plans to add an export capability later this year to allow other vendors' software to analyze the acquired data.

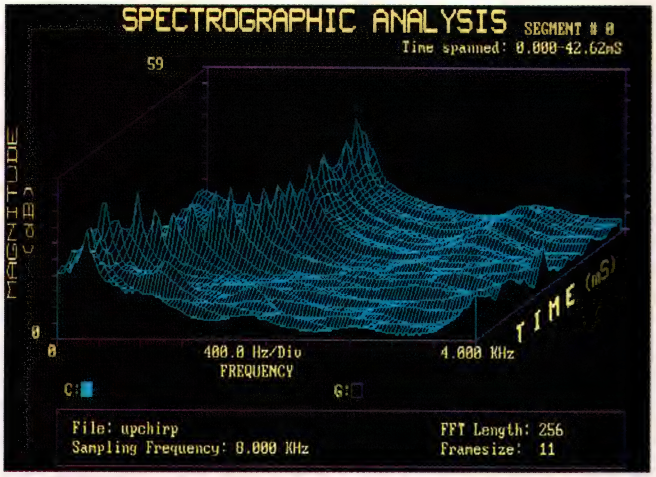
Some menu-driven data-acquisition packages allow you to use bus-based instruments from a variety of vendors. For example, Hem Data's $495 Snapshot Storage Scope can operate analog input cards for the IBM PC bus from Metrabyte, Analog Devices, Data Translation, Burr-Brown, and Microway. The package acquires data from as many as 16 channels concurrently and can take as many as 32,000 12-bit samples at rates ranging from 2 samples/hour to 130,000 samples/sec.

Similarly, Unkel Software's Unkelscope—a family of three menu-driven software packages costing $125 to $549—supports bus-based analog input boards from more than a dozen vendors. Unkelscope Junior, the lowest-cost package, can acquire data from one to four channels concurrently, collecting as many as 1024 data points/channel. Unkelscope Level 2, the high-end package, handles eight channels with 4096 samples/channel and can take 16,384 samples in single-channel mode. All versions of Unkelscope store data in the Lotus 1-2-3 or Math Works' PC-Matlab data formats. These products all run on MS-DOS-based computers.

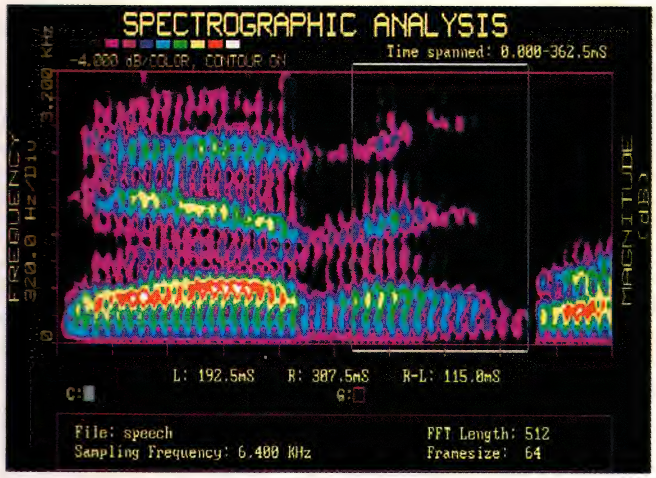
Lab software for the Macintosh

Apple Macintosh owners haven't been left out of the laboratory-automation game. The menu-driven Labtech Notebook from Laboratory Technologies comes in versions running on IBM PCs and compatible computers ($995 to $1195) and in Macintosh-based versions ($995). The package acquires data from a variety of sources (IEEE-488, RS-232C, and bus-based boards), stores the data in disk files, plots the data, and performs some data analysis. You can run the program as a background task at typical data-acquisition rates, and you can acquire samples as slowly as one every three years or as rapidly as your data-acquisition hardware allows. The software can handle 16 input or output devices simultaneously and can control output channels as well. It can also use data from one or two input channels to control an output based on the sampled data.

Labtech Notebook's analysis capabilities include nonlinear curve fitting and FFTs. If you need more analysis flexibility, consider the $295 Labtech real-time access package, which delivers real-time data that's compatible with analysis programs from other vendors such as Lotus 1-2-3 and BBN Software's RS/1. In this mode,



(a)



(b)

***The excellent graphic-display capabilities** of today's PCs allow laboratory-automation software to present data in a variety of ways so you can pick a format that best matches your data. Hypersignal-Plus from Hyperception can display 3-dimensional spectrographic data as a series of 2-dimensional plots **(a)** or, by using color, can add the third dimension to a flat screen display **(b)**.*

Labtech Notebook appears to these other application programs as a disk data file, but the programs receive real-time, not stored, data.

The MacAdios (Macintosh analog/digital I/O system) Manager and MacAdios Manager II from GW Instruments work with the company's data-acquisition products for the original (slotless) Macintosh computer and the Macintosh II, respectively. Both programs offer menu-driven control over the MacAdios data-acquisition hardware. Because of the graphic interface, Macintosh computers are well suited to menu-driven program control.

Either version of the MacAdios Manager lets you view four analog or 32 digital waveforms at once. In addition, the packages can perform extensive analysis of sampled waveforms—they can perform FFTs, inverse FFTs, spectrum and statistical analysis, waveform arithmetic (addition, subtraction, multiplication, and division), integration, differentiation, and convolution. You can modify the sampled data either by using a graphic editor to alter plotted data or by using a table editor to change specific sampled values. GW Instruments provides the MacAdios Manager at no extra charge to customers who purchase the $2500 MacAdios 411 data-acquisition system. The MacAdios 411 interfaces to the original versions of the Macintosh. The MacAdios Manager II costs $1000; it works with the company's $1290 MacAdios II data-acquisition board for the Macintosh II.

Several vendors offer data-acquisition software for instruments that aren't married to a particular bus. Connecticut MicroComputer Inc (CMC) specializes in stand-alone instrumentation that communicates with computers over a variety of standard interfaces. The company offers the 16-channel D1216 and 32-channel D1232 analog-input modules, which have IEEE-488, RS-232C, RS-422, or RS-485 interfaces. The D1216 costs $995; the D1232 sells for $1295. As long as you write the necessary software, these modules can communicate with any PC that incorporates the appropriate interface. Further, you can use CMC's menu-driven ACQ-D12 data-acquisition program with an IBM PC or a compatible computer to control several D1216s or D1232 modules. The software is free when you purchase the hardware.

For large data-acquisition jobs, CMC offers an integrated network, CMCNet II, that controls as many as 1600 instruments and peripherals from one RS-232C port on an IBM PC. The network's menu-driven control software, Netdrive, gives you manual control of any device on the network and can automatically collect data from designated devices. The company includes Netdrive with the CMCNet II controller board, which costs less than $100. A CMCNet II device module links one RS-232C device to the network and costs $150 to $200. Both Netdrive and ACQ-D12 can store acquired data in Lotus 1-2-3 and Wildfire Systems Group's Danal data-file formats.

Capitol Equipment's $349 Acquisition Engine, a memory-resident program for IBM PCs and compatible computers, makes data acquisition from IEEE-488, RS-232C, and some card-based instruments a back-

You can turn to stand-alone instruments for tasks that bus-based instruments don't have the features or sophistication to handle.

ground task. You set up the Acquisition Engine to take measurements at timed intervals or upon the occurrence of a hardware interrupt; you use ASCII script files to configure the engine for your particular data-acquisition task. The program saves acquired data in RAM, and you can save this data in a disk file at any time. In addition, application programs can use ASCII data streams to communicate with the Acquisition Engine: They print to and read from three MS-DOS devices created when you initialize the program. For debugging purposes, you can also run the Acquisition Engine in the foreground, as you would any other application program.

Software for stand-alone instruments

Sometimes, bus-based data-acquisition boards lack sufficient bandwidth or sophistication to take the measurements you need. In these instances, you can turn to stand-alone instruments that can communicate with PCs over standard interfaces. If you have a Tektronix 2220 or 2230 digital storage oscilloscope, for example, one of two $50 software packages from Tektronix can help you transfer waveforms from your scope to an IBM PC or a compatible computer. The S49Z201 RS-232C utility software package operates as a stand-alone applications package. Using the PC's function keys, you can set up your scope to take measurements. The package then captures the digitized waveform and can reproduce the scope's display on the PC's screen. The software is written in interpretive IBM BasicA, so you can modify it to better fit your needs.

In contrast, the company's S49Z202 Turbo Digitizer package does nothing by itself. The package consists of several library modules for Borland International's $99.95 Turbo Pascal compiler that you can link into programs that you write. This utility package helps you control and read data from your DSO over the IEEE-488 bus. It provides I/O handlers for the National Instruments PC2 and PC2A IEEE-488 controller boards. Turbo Digitizer gives you more control over the scope's operation than does the company's menu-driven program, but it exacts a penalty for this flexibility: You must write a program in Turbo Pascal to perform the measurements, analyze the data, and then display the results on the PC's screen or plot them on a hard-copy device such as a plotter or printer.

Tailoring languages for data acquisition

Language extensions and subroutine libraries such as Turbo Digitizer help you use some of the more popular, general-purpose programming languages in data-acquisition applications. Several companies, however, believe that because of the unique and stringent I/O-performance requirements placed on computers by measurement applications, programming languages used for acquiring data should be tailored from scratch. For instance, the Asyst family of laboratory-automation software packages from Asyst Software Technologies is based on the Forth programming language, but the company has augmented its version of the language to better support I/O, data analysis, and graphing. For acquiring data, the software supports bus-based analog- and digital-I/O boards from a variety of manufacturers and IEEE-488 controller boards from several vendors. Asyst costs $1695 to $2295, depending on the number of modules you buy.

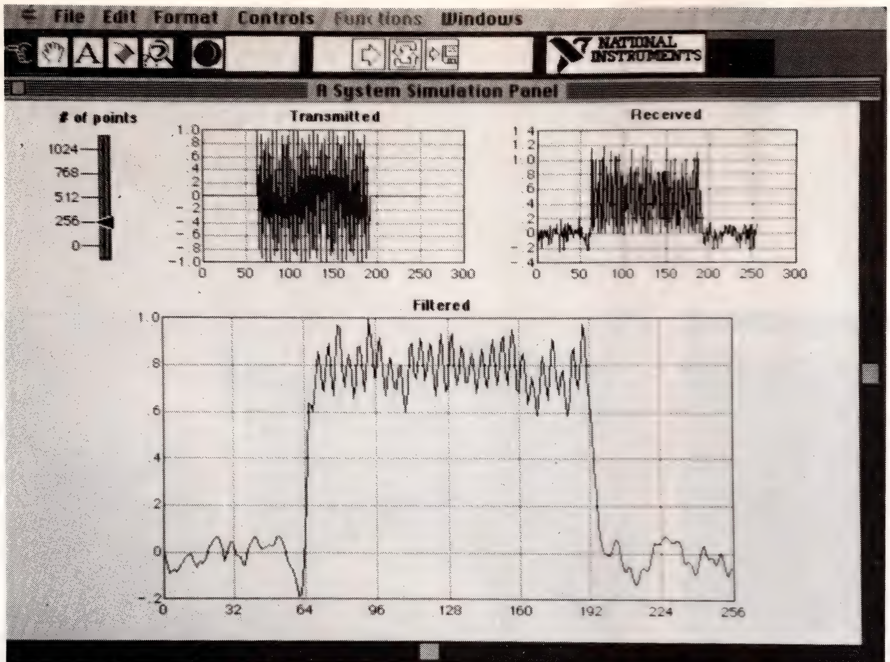
The Asyst software system runs on IBM PCs and compatible computers and supports the LIM (Lotus, Intel, and Microsoft) expanded memory specification for storing and processing large data blocks. The soft-

Conquering the data-format Tower of Babel

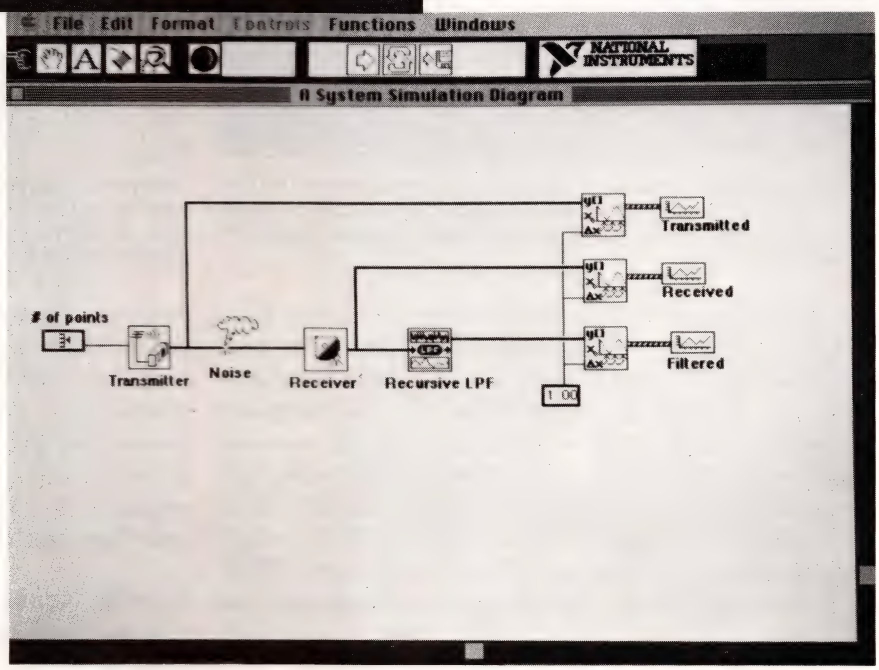
Rapid Systems, a vendor of PC-based laboratory-automation products, ran into a growing problem as its product line expanded: Data-storage formats for its data-acquisition products proliferated almost as fast as the products themselves. Worse, the company realized, this problem prevailed throughout the industry. Almost every software company had invented its own data-storage format, and few companies seemed interested in organizing a standardization effort.

Although many data-acquisition products and software packages can exchange data stored in several of these formats, chances are good that unless you plan carefully, your new data-collecting instruments won't generate files that your post-processing software can digest. This problem prompted Rapid Systems to develop the R901 universal file translator, a $495 program that translates files from one of several different data formats to another. The formats it understands include Lotus 1-2-3, Ashton-Tate's dBase II and III, DSP Development's DADiSP, MathCAD, Signal Technology's ILS-PC, Asyst, Labtech Notebook, Rapid Systems, and ASCII.

(a)



(b)



***You can simulate systems** and also acquire, analyze, and present experimental data with National Instruments' Labview graphical programming language. The front panel for this simulated transmission system **(a)** shows the transmitted, received, and filtered versions of a signal. Behind the front panel **(b)**, you can see the program that generated this simulation.*

ware can also perform analysis on disk files, which is useful when the acquired data is too large to fit into the computer's RAM. Asyst's waveform-processing functions include FFT, inverse FFT, correlation, weighted and nonweighted curve fitting, user-defined and nonlinear curve fitting, and least-squares regression. The package also performs matrix math and statistical analysis.

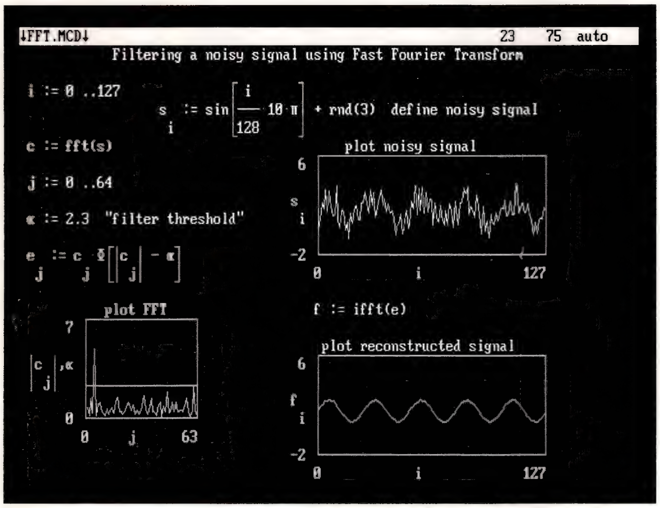
Once you've analyzed your captured data, Asyst can present the results in a variety of formats, including x-y and contour plots, pie and bar charts, superimposed plots of multiple waveforms, and windowed graphics. The charting module can scale your plots automatically, and it produces logarithmic, linear, and polar plots.

A strong proponent of the tailored-language approach to laboratory automation is Hewlett-Packard Co. For more than a decade, Hewlett-Packard has offered its own dialect of Basic augmented with special-purpose statements to enhance the language's IEEE-488 control capabilities. Originally, the company offered this enhanced Basic only for its proprietary computer architectures.

However, acknowledging the undeniable penetration of IBM's PC architecture into the engineering environment, Hewlett-Packard finally created a version of its Basic for PCs as well as a coprocessor card to run the language. Called the HP 82300A, this $1595 card for personal computers incorporating the IBM PC/AT bus runs the same Basic originally designed for the company's Model 9000 Series 200 and 300 workstations. In addition to the 68000 μP, the card includes 512k bytes of RAM (expandable to 4M bytes), an IEEE-488 controller, and the Instrumentation Basic language.

If you happen to be a devotee of Hewlett-Packard's

Apple Macintosh owners need not feel left out of the laboratory-automation game.



General-purpose analysis programs can perform extensive analysis of sampled signals. Here, for example, Mathcad from Math Soft both performs an FFT on a noisy signal and produces a filtered waveform on the same screen.

Laboratory-automation software packages can save you a lot of time by helping you acquire, analyze, and present experimental data. A variety of packages are available that operate with popular personal computers and instruments. (Photo courtesy Metrabyte)

HP-41 calculator, you'll be interested to know that Eclipse Logic's $275 ELI-488 calculator-emulation program can endow your IBM PC or compatible computer with that calculator's capabilities and programming language, augmented with IEEE-488-bus control statements. ELI-488 gives you both interactive and programmed control over the IEEE-488 bus as well as the analytical capabilities of the HP-41. The product requires a PC and National Instruments' $395 GPIB-PCII controller board to provide the IEEE-488 bus interface.

Windows give you a better view

Displaying multiple windows on a PC's screen can be quite valuable in a data-acquisition application in which more than one instrument is taking measurements during a test or when you want to see raw data displayed along with an analysis of that data. Summation's $2950 TestWindows development environment includes and employs Microsoft's Windows package for MS-DOS. It creates a technique that allows you to generate commands for IEEE-488-based instruments fairly easily.

Through one window, TestWindows lets you use English-like commands to exercise interactive control over an instrument. The company's Sigma Users Group maintains a library of TestWindows definitions for IEEE-488 instruments from a variety of manufacturers. These definitions allow TestWindows to translate high-level commands into character strings, which the program then sends over the IEEE-488 bus. After you've determined the proper sequence of commands to make an instrument perform a desired measurement, the package's TestBasic language can scan your interactive control window, extract the sequence of commands you used, and convert these commands to a commented sequence of program statements that you can include in your final test program.

Graphic languages redefine programming

A few companies have introduced products that implement graphic programming languages for laboratory-automation applications. For example, Wavetek's $3990 WaveTest programming language has more in common with flowcharts than with the usual lists of program statements. The company has replaced traditional programming-statement syntax with 19 graphical representations, or icons, of equivalent programming constructs. This approach makes it impossible for you to forget a semicolon or misplace a comma in your program—the icons don't use such punctuation.

Another graphic programming language, Strawberry Tree Computers' $495 Analog Connection Workbench for Apple's Macintosh computers, allows you to create a data-acquisition program simply by "wiring up" (drawing lines between) various icons. The program includes symbols that represent data-acquisition circuits residing on the company's family of Analog Connection data-acquisition boards; it also has symbols for various mathematical functions performed by the

You can view your data in a variety of ways *by using PC software that provides data analysis and graphic display. This 3-dimensional spectral display, for example, was generated by the $2495 Interactive Laboratory System (ILS) from Signal Technology Inc.*

computer, including metering, charting, and alarm generation.

A $1995 programming environment from National Instruments called Labview for Macintosh II computers, provides a more comprehensive approach to a graphic programming language for data-acquisition applications. Labview is based on icons called virtual instruments (VIs). Behind a VI icon resides a graphic representation of the instrument's front panel. However, no such front panel need actually exist: A Labiew front panel is simply a metaphor for the measurements taking place. You can give A/D-converter boards front panels and create rearranged or simplified front panels for stand-alone instruments. Labview supports the company's data-acquisition boards for the Macintosh II, as well as instruments connected to any version of the Macintosh over RS-232C or IEEE-488 communication ports. The company offers IEEE-488 controller boards for the entire Macintosh computer family.

Labview's program representation is a block diagram, so it lacks the cumbersome paraphernalia of traditional programming languages: It has no line numbers, punctuation, and statement delimiters. For example, to create a spectrum analyzer, you draw a line from the icon for an appropriate data-collecting instrument —say, an A/D converter card—to a spectrum-analysis icon. In the Labview syntax, spectrum analysis is a single function, just as such an operation might be a single subroutine call in a more conventional programming language. You connect the output of the spectrum-analysis module to a graphing icon, which, in turn, drives a display icon. Simply wiring these modules in series prompts Labview to perform the appropriate tasks.

Hierarchical programming reduces complexity

In addition, you can hide a lot of your program's detail when you use Labview, because the package permits the hierarchical nesting of icons. Labview's icon syntax includes programming structures (sequence, case, For loop, While loop), arithmetic operators, timing elements, I/O-control elements, string operators, and transcendental functions. The package's instrument library contains more than 100 preconfigured virtual instruments for existing instruments from several manufacturers. Once you create a data-acquisition program with Labview, you can hide it behind a front panel for the entire operation, essentially creating a new virtual instrument. You build these front panels from a collection of graphic images, including icons of control knobs, switches, and graphic-output devices (such as meters and strip-chart recorders).

Graphic programming languages such as the Analog Connection Workbench and Labview represent a data-flow approach to software creation. You specify only how data flows from one function—represented by an icon—to the next. You don't concern yourself with nitpicking syntax punctuation or with calling parameter sequences. In the future, this programming style could prove useful on multiprocessing computer systems that can assign individual processors to execute the code represented by each icon. Although current implementations of these graphic programming languages don't run on multiprocessing computer systems, vendors could clearly take that approach in their efforts to increase the products' performance, because the basic concepts of the products fit well with multiprocessing systems.

Spreadsheets for laboratory automation

A few vendors have decided that the now-familiar spreadsheet metaphor works well for automating the laboratory. Spreadsheets really started to proliferate when Lotus Development Corp introduced its Lotus 1-2-3, which resides on several million MS-DOS systems around the world, including quite a few PCs on engineers' desks. Lotus Development created the $495 Lotus Measure, an add-on package for Lotus 1-2-3 that provides the spreadsheet program with data-acquisition capabilities. With Measure's macro commands, you

Graphic programming languages let you forget about the nitpicking punctuation requirements of conventional languages.

can take readings from IEEE-488, RS-232C, and bus-based instruments and insert the data directly in designated spreadsheet cells. Measure also provides you with an interactive mode for manual instrument control. National Instruments recently acquired all rights to the Lotus Measure package from Lotus Development, so any questions abuot the package should be referred to National Instruments.

Manufacturers of laboratory-automation software

For more information on laboratory-automation software products such as those discussed in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

American Advantech Corp
1460 Tully Rd, Suite 602
San Jose, CA 95122
(408) 293-6786
Circle No 650

Analog Devices Inc
Industrial Automation Div
Box 9106
Norwood, MA 02062
(617) 329-4700
TWX 710-394-6577
Circle No 651

Analysis Technology Co
3914 Miami Rd
Cincinnati, OH 45227
(513) 561-1100
Circle No 652

Ariel Corp
110 Greene St
New York, NY 10012
(212) 925-4155
Circle No 653

Asyst Software Technologies Inc
100 Corporate Woods
Rochester, NY 14623
(716) 272-0070
Circle No 654

B&C Microsystems
355 W Olive Ave
Sunnyvale, CA 94086
(408) 730-5511
TLX 984185
Circle No 655

BBN Software Products
10 Fawcett St
Cambridge, MA 02238
(617) 873-5000
TLX 921470
Circle No 656

Binary Engineering
100 Fifth Ave
Waltham, MA 02154
(617) 890-1812
Circle No 657

Borland International
4585 Scotts Valley Dr
Scotts Valley, CA 95066
(408) 438-8400
TLX 172373
Circle No 658

Burr-Brown Corp
Box 11400
Tucson, AZ 85734
(602) 746-1111
TWX 910-997-0735
Circle No 659

BV Engineering
2023 Chicago Ave, Suite B13
Riverside, CA 92507
(714) 781-0252
Circle No 660

Cadnetix Corp
5775 Flatiron Parkway
Boulder, CO 80301
(303) 444-8075
Circle No 661

Canetics Inc
Box 70549
Pasadena, CA 91107
(818) 584-0438
Circle No 662

Capitol Equipment Corp
99 S Bedford St #107
Burlington, MA 01803
(617) 273-1818
Circle No 663

Connecticut Microcomputer Inc
Box 186
Brookfield, CT 06804
(203) 354-9396
TWX 710-456-0052
Circle No 664

Daisi Electronics Inc
Box K
Newton Square, PA 19073
(215) 353-2203
Circle No 665

Data Translation Inc
100 Locke Dr
Marlboro, MA 01752
(617) 481-3700
TLX 951646
Circle No 666

Dianachart Inc
129 Hibernia Ave
Rockaway, NJ 07866
(201) 625-2299
Circle No 667

DSP Development Corp
One Kendall Square
Cambridge, MA 02139
(617) 577-1133
TWX 910-250-2781
Circle No 668

Durham Technical Images
Box 72
Durham, NH 03824
(603) 868-7203
Circle No 669

Eclipse Logic Inc
Box 2003
Huntington Park, CA 92055
(818) 955-5718
Circle No 670

Erbtec
2760 29th St
Boulder, CO 80301
(303) 447-8750
Circle No 671

Golden Software Inc
Box 281
Golden, CO 80402
(303) 279-1021
Circle No 672

GW Instruments Inc
Box 2145
Cambridge, MA 02141
(617) 625-4096
Circle No 673

Hart Scientific
177 W 300 South
Provo, UT 84601
(801) 375-7221
Circle No 674

Heath/Zenith Co
Computer Based Instrument Group
Hilltop Rd
St Joseph, MI 49085
(616) 982-3200
TLX 275411
Circle No 675

Hem Data Corp
17025 Crescent Dr
Southfield, MI 48076
(313) 559-5607
Circle No 676

Hewlett-Packard Co
1820 Embarcadero Rd
Palo Alto, CA 94303
Phone local office
TWX 910-373-1267
Circle No 677

Hyperception
9550 Skillman, LB 125
Dallas, TX 75243
(214) 828-3508
Circle No 678

Intelligent Instrumentation Inc
1141 W Grant Rd, #131
Tucson, AZ 85705
(602) 624-2434
TWX 910-997-0735
Circle No 679

Interactive Microware Inc
Box 139
State College, PA 16804
(814) 238-8294
TLX 705250
Circle No 680

International Data Acquisition and Control
Box 397
Amherst, NH 03031
(603) 673-0765
Circle No 681

IOTech Inc
25971 Cannon Rd
Cleveland, OH 44146
(216) 439-4091
TWX 650-282-0864
Circle No 682

ISI Software
3501 Market St
Philadelphia, PA 19104
(215) 386-0100
TLX 845305
Circle No 683

John Fluke Mfg Co
Box C9090, M/S 250C
Everett, WA 98206
(206) 356-5400
Circle No 684

Keithley Instruments Inc
28775 Aurora Rd
Cleveland, OH 44139
(216) 248-0400
TLX 985469
Circle No 685

The $795 DADiSP Worksheet from DSP Development Corp runs on IBM PCs and compatibles and performs 160 data-manipulation and -analysis functions, including signal arithmetic, signal calculus, waveform generation, Fourier analysis, frequency-domain analysis, correlation, trigonometric calculations, and statistics. The package is menu driven, and it supports as many as 64 windows.

Laboratory Technologies Corp
400 Research Dr
Wilmington, MA 01887
(617) 657-5400
TLX 989695
Circle No 686

Lawson Labs Inc
5700 Raibe Rd
Columbia Falls, MT 59912
(406) 387-5355
Circle No 687

LeCroy Corp
700 Chestnut Ridge Rd
Chestnut Ridge, NY 10977
(914) 425-2000
TWX 710-577-2832
Circle No 688

Lotus Development Corp
55 Cambridge Parkway
Cambridge, MA 02142
(617) 577-8500
Circle No 689

Math Works Inc
20 N Main St, Suite 250
Sherborn, MA 01770
(617) 653-1415
TWX 910-240-5521
Circle No 690

Mathsoft Inc
One Kendall Square
Cambridge, MA 02139
(617) 577-1017
Circle No 691

Metrabyte Corp
440 Myles Standish Blvd
Taunton, MA 02780
(617) 880-3000
TLX 503989
Circle No 692

Microstar Laboratories
2863 152 Ave NE
Redmond, WA 98052
(206) 881-4286
TWX 510-601-3473
Circle No 693

Microway
Box 79
Kingston, MA 02364
(617) 746-7341
Circle No 694

National Instruments
12109 Technology Blvd
Austin, TX 78727
(512) 250-9119
TLX 756737
Circle No 695

Omega Engineering Inc
Box 4047
Stamford, CT 06907
(203) 359-1660
TLX 996404
Circle No 696

Orion Instruments
702 Marshall St
Redwood City, CA 94063
(415) 361-8883
TLX 530942
Circle No 697

PennWell Publishing Co
Box 21288
Tulsa, OK 74121
(918) 835-3161
Circle No 698

Personal Computing Tools Inc
101 Church St, Unit 12
Los Gatos, CA 95032
(408) 395-6600
Circle No 699

Qua Tech Inc
478 Exchange St
Akron, OH 44304
(216) 434-3154
Circle No 700

Rapid Systems Inc
433 N 34th St
Seattle, WA 98103
(206) 547-8311
TLX 265017
Circle No 701

Scientific Programming Enterprises
Box 669
Haslett, MI 48840
(517) 339-9859
Circle No 702

Signal Technology Inc
5951 Encina Rd
Goleta, CA 93117
(805) 683-3771
Circle No 703

Soltec Corp
Sol Vista Park
San Fernando, CA 91340
(818) 365-0800
TLX 4943094
Circle No 704

SPSS Inc
444 N Michigan Ave
Chicago, IL 60611
(312) 329-2400
TWX 910-221-1396
Circle No 705

Strawberry Tree Computers Inc
160 S Wolfe Rd
Sunnyvale, CA 94086
(408) 736-3083
Circle No 706

Summation Inc
11335 NE 122nd Way
Kirkland, WA 98034
(206) 823-8688
TLX 152219
Circle No 707

Talton/Louley Engineering
6376 Rancho Mission Rd,
Suite 414
San Diego, CA 92108
(619) 565-6656
Circle No 708

Tektronix Inc
Box 1700
Beaverton, OR 97075
(503) 627-7111
TWX 910-467-8708
Circle No 709

Universal Technical Systems Inc
1220 Rock St
Rockford, IL 61101
(815) 963-2220
Circle No 710

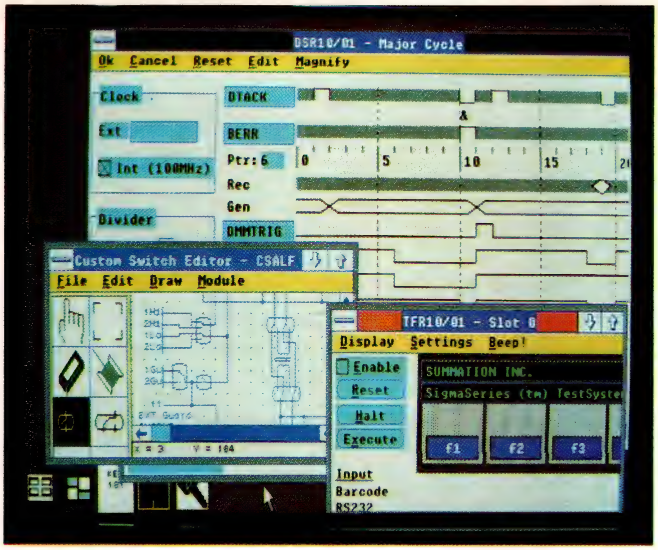
Unkel Software Inc
62 Bridge St
Lexington, MA 02173
(617) 861-0181
TWX 910-240-9722
Circle No 711

Wavetek Corp
Box 85434
San Diego, CA 92122
(619) 450-9971
TLX 756953
Circle No 712

WestAq Corp
Box 127
Parachute, CO 81635
(303) 285-7700
Circle No 713

World Precision Instruments Inc
375 Quinnipiac Ave
New Haven, CT 06513
(203) 469-8281
Circle No 714

Ziatech Corp
3533 Roberto Ct
San Luis Obispo, CA 93401
(805) 541-0488
TLX 4992316
Circle No 715



Windowing software gives you multiple, simultaneous views *of your experimental setup. This display, generated by Summation's TestWindows package, shows views of the experimental setup, a control panel, and captured waveforms.*

Each DADiSP window contains a waveform or an equation. Waveforms are placed in virtual storage, so waveforms larger than the computer's RAM can still occupy a window. DADiSP automatically pages, or transfers, sections of large waveforms on and off the disk during computations. The software can operate on the waveforms by using equations created from the data-manipulation and -analysis functions. You can also scroll through, zoom in on, expand, compress, and edit a waveform contained in a window. DADiSP 488, a $195 companion package, adds IEEE-488 data-acquisition capabilities to the main product.

Software helps you present your findings

If you select a software product that only acquires data, you can add charting and analysis software from other vendors to complete your personal laboratory-automation system. For example, if you merely need to display and plot the data you've captured, you might select the $95 PC Plot package from BV Engineering. PC Plot runs under MS-DOS and accepts data files in ASCII, Lotus 1-2-3, and Labtech Notebook formats. The package displays graphs with as many as three axes having linear, logarithmic, and semilogarithmic scales; each graph can have as many as six plotted waveforms. You can also ask the program to scale the axes automatically. If you want hard-copy plots, you can have the company's $95 PDP (plotter driver program) make them.

Binary Engineering's $275 Tech*Graph*Pad package for IBM PCs and compatible computers plots data and equations on several types of graphs, including linear, linear-logarithmic, log-log, and polar graphs. The program can also perform some data manipulation in the form of curve smoothing using spline, Bezier, or Savitsky-Golay methods. Tech*Graph*Pad can read data files in Lotus 1-2-3 (WRK, WK1, and WKS), Lotus Symphony, Labtech Notebook, and ASCII formats.

Should you have considerable data-analysis requirements, you can choose from a few very powerful software products that are specifically designed for engineering and scientific data analysis. One such package that tends to defy traditional classification—it's not a spreadsheet or a database—is Mathsoft Inc's Mathcad, a $349 numerical-analysis program for computers running MS-DOS. Mathcad works a little like a spreadsheet program, but treats the PC's CRT display as though it were a blank sheet of paper. In other words, you can enter equations, define assumptions, and generate graphs anywhere on the screen.

Mathcad's built-in functions include statistics, interpolation, FFTs, random-number generation, and Bessel functions. From these basic function types you construct equations to perform the analysis on your captured data. Mathcad can read ASCII data from files generated by other programs and can display analysis results on the PC's screen or plot them on printers and plotters.

Another general-purpose analysis tool, PC-Matlab from Math Works, performs matrix computations without user programming. You can buy the product for MS-DOS systems ($695), for 80386-based MS-DOS systems ($1495), for 80386-based MS-DOS systems that incorporate Weitek's 1167 math coprocessor ($1995), and for the Apple Macintosh ($895). Each version of PC-Matlab includes a signal-processing toolbox that performs FFTs, inverse FFTs, discrete Fourier transforms (DFTs), inverse DFTs, 2-dimensional FFTs, 2-dimensional inverse FFTs, filtering, frequency-response and spectral analysis, and cross-correlation. The package can also compute other functions, such as power spectral densities and coherence. For signal-processing computations, you store sampled-data signals as vectors. PC-Matlab imports data files stored in ASCII, binary, and DIF (digital interchange format) representations. It plots results on linear, log, semilog, and polar graphs, as well as 3-dimensional mesh surfaces.

TK Solver Plus, a $395 package from Universal Technical Systems, lets you use equations to create mathematical models of your experiments. The product's models accommodate formulas, design constraints, and material properties. It runs on IBM PCs and compatible computers. For captured data, TK Solver Plus accepts DIF, Lotus WKS, and ASCII data formats. A general-purpose computational tool such as TK Solver Plus can perform extensive data transformations, including integration and differentiation, smoothing, matrix manipulation, and statistical analysis.

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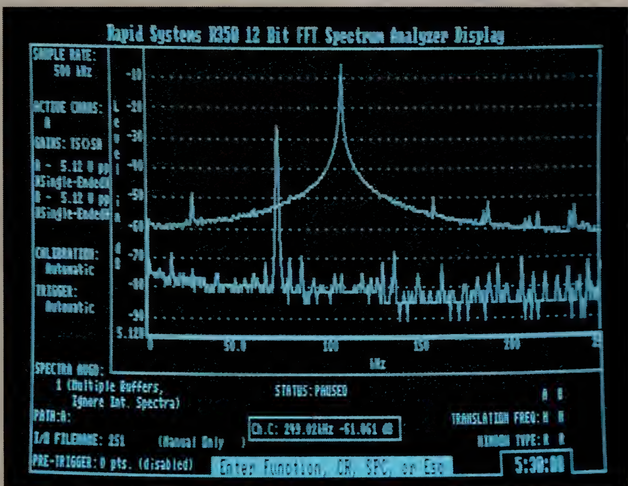
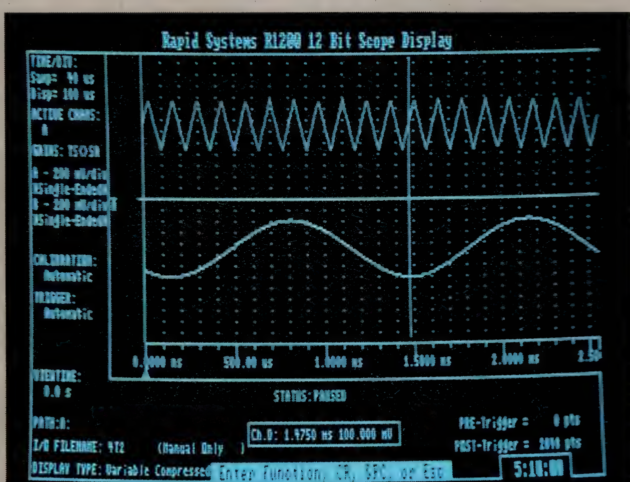


The R350 is a PC-based 12-bit, 2-channel, 500 KHz, real-time, FFT spectrum analyzer. Sample 2 channels simultaneously. 32K data buffers. Autosave spectrums to hard or floppy disk. Two modes of spectrum averaging. Fully differential inputs. Linear or log amplitude scaling. Amplitude and frequency cursor. Display spectrums 5 to 10 times a second. Print, store, retrieve and overlay spectrums. 500 KHz anti-aliasing filters on each channel, 80db of dynamic range.



The R350 is a PC-based 12-bit Digital Oscilloscope. Sample 2 channels simultaneously at 1 MHz. 32K data buffers per channel. EMI protected metal case with power supply. Switchable differential or single ended input impedance. Software-selectable gain ranges allow resolution of 200μv to 500 volts. Full analog and 100% digital triggering. Trigger adjust potentiometer. Fully differential inputs for signal integrity. Vertical waveform zooming. Autosave. Software drivers for "C", BASIC, and Turbo-Pascal.

At Rapid Systems, 12 bit spectrum analyzers and digital oscilloscopes are no longer separate and distinct instruments, each with its own high cost.

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CIRCLE NO 97

Some data-analysis software targets specialized applications. Hypersignal-Plus, for example, is a menu-driven package from Hyperception that specifically performs DSP functions, such as FFTs, inverse FFTs, convolution, autocorrelation, power spectra estimation, and spectrographic analysis. The program accepts data in several binary formats and ASCII format. Once you've determined the sort of processing required by your input data to achieve a desired result, Hypersignal-Plus can help you create FIR (finite impulse response) and IIR (infinite impulse response) filter coefficients for digital signal processors from Texas Instruments and AT&T. The package costs $489.

Another product that can help you design digital filters is PC Data Master from Durham Technical Images. This $115 package contains several stand-alone software modules that you organize through the package's MS-DOS shell using a batch-language command file and software pipes to route data from one module to the next. PC Data Master contains general-purpose analysis and plotting modules, as well as a group of DSP utilities. One of its DSP utilities helps you generate FIR-filter coefficients. In addition, you can use the package to acquire data from Metrabyte's DAS-8 and -16 A/D-converter boards.

Because the available laboratory-automation packages vary widely, you might understandably have a tough time deciding which products fit your application. Fortunately, by providing manuals and demonstration disks at little or no cost, many software vendors give you an opportunity to sample their wares. Be sure to ask about demonstration packages when you contact a vendor. These "trial-size" versions of the full packages let you get the feel of the software, and some demo packages allow you to perform limited experiments, analyze a little data, and make a few plots. If you're shopping for laboratory-automation software, try out some demos before making a final decision. Then you'll be ready to acquire one or more of these software products and get some real engineering assistance out of that PC on your desk. **EDN**

Reference

Comparing data-acquisition software for personal computers, Application note #804, Keithley Instruments Inc, Cleveland, OH.

Article Interest Quotient (Circle One)
High 470 Medium 471 Low 472

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Xilinx Programmable Gate Arrays have densities up to and including 9000 honest gates. How dense can you get? We aim to keep finding out.

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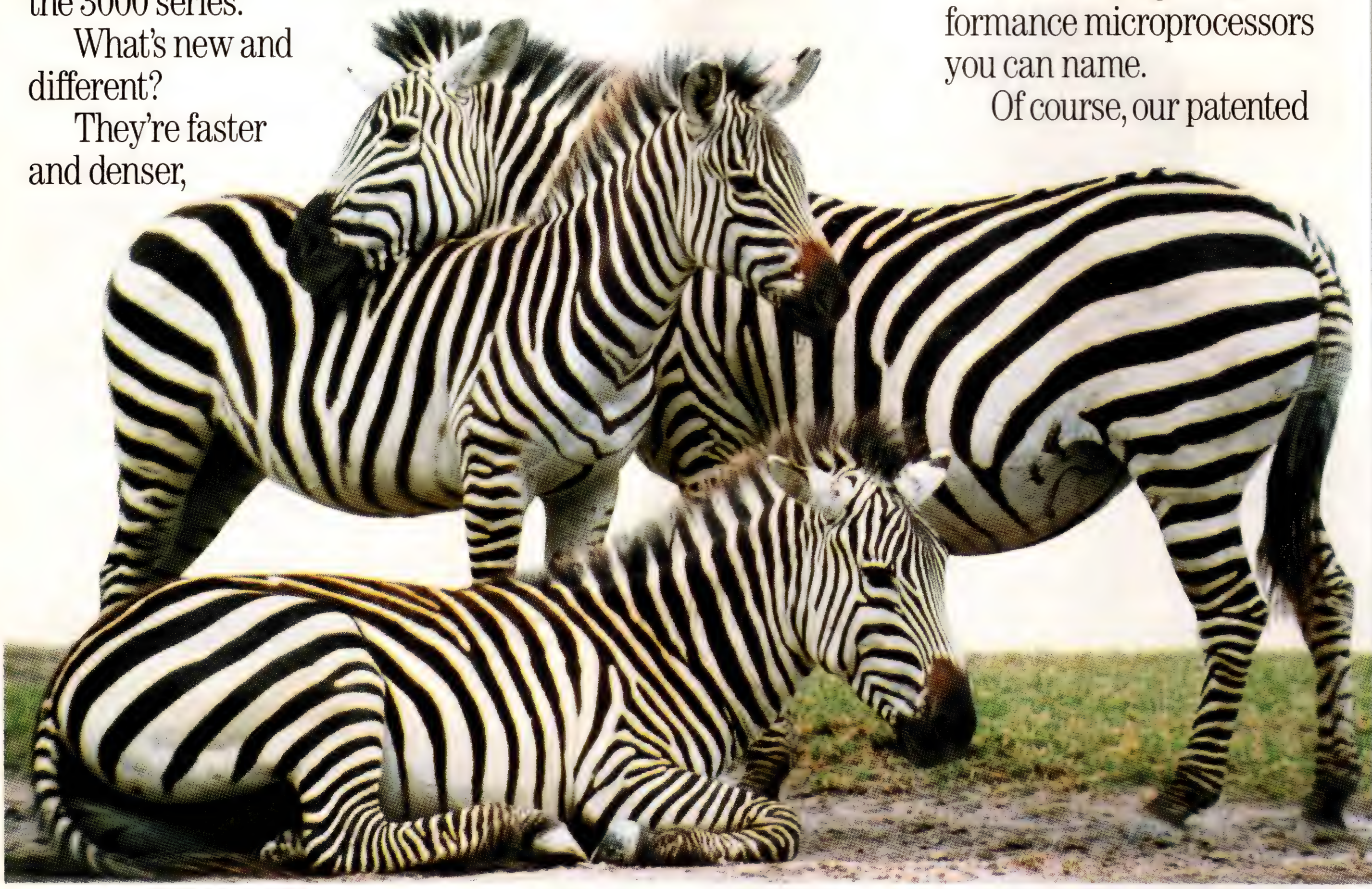

Are the zebra's stripes white-on-black or black-on-white? Should you buy the Programmable Gate Array for its cost-effectiveness, short development cycle, off-the-shelf availability, or its 100% testability? Yes to both questions.

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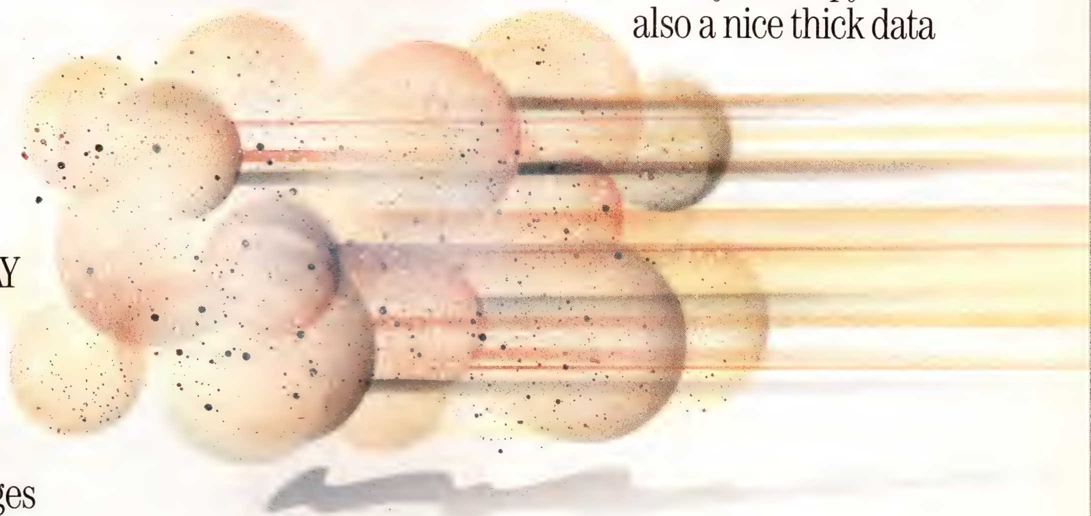

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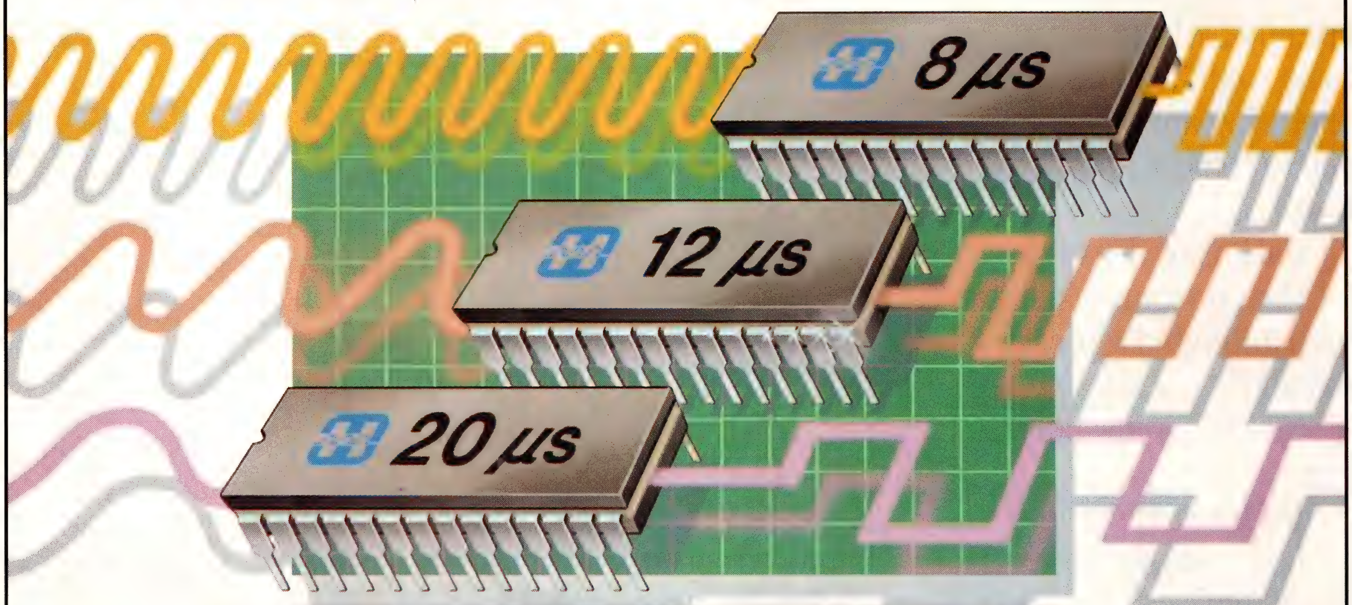
For information contact: Harris Systems Ltd., Semiconductor Sector, Eskdale Road, Winnersh, Wokingham, Berks, RG11 5TR, England.



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Support chips are in transition from discretes to ASICs

The devices in EDN's eleventh annual μP Support-Chip Directory typify the changes afoot in μP system architecture—the wider use of platform chip sets and the introduction of 32-bit RISC chips.

Robert H Cushman, *Special Features Editor*

Today's support chip is tommorrow's ASIC cell. If you're a devotee of EDN's Annual μP Support-Chip Directory, you know this statement to be true. This year, though, due to the current escalation in VLSI progress, you can almost envision the demise of support chips as discretely packaged devices.

After all, how can a μP-based product continue to afford support functions such as UARTs (or, even worse, SSI glue parts) that take up so much board space? Today's big 300- to 500-mil-on-a-side chips can integrate nearly a million transistors, and it's hard to justify having separate packages for functions that only need a thousand or so transistors. Such inefficient support-device packaging defeats what seems to be the goal of so many systems being designed these days—to cram an entire 32-bit superminicomputer onto an IBM PC card!

The parallel and serial I/O ports and timers of **Tables 1A, 1B,** and **1C** are examples of support functions that don't take up much silicon area and therefore are prime candidates for incorporation into other chips. In small systems, you can incorporate them in 1-chip μCs; in larger systems, you can incorporate them in support chip sets (such as those in **Table 2**). Typically, they are squeezed onto the periphery of the larger chips, where they are near their I/O pads. Actually, the need for I/O pads—especially in the case of 16- and 32-bit parallel ports—is a good reason to put the functions on larger chips: The larger chips have longer edges and more pins.

While perusing the tables, you will notice some new, more-complex I/O devices such as SCSI Bus interfaces. For the time being at least, these types of chips possess the complexity to warrant stand-alone packaging. Theoretically IBM's Micro Channel Bus could be included in this category as parallel I/O, or the bus's chips could be considered bus controllers, which would place them in the catch-all section of **Table 1G.** Nonetheless, because the Micro Channel Bus is part of the high-volume IBM PS/2 "platform," you'll most likely always find it incorporated into the PS/2 chip sets (see **Table 2**).

Number crunching should be on μP

The fourth table in the directory, **Table 1D,** covers number-crunching functions. At present, you'll find the population of these chips still healthy and growing. As you can see, the table contains some powerful IEEE-standard floating-point accelerators that can significantly boost a μP's Whetstone benchmark.

DSP chips are the most extreme case of high-performance number crunching.

If you analyze the architectural schemes of μP systems, however, you'll see that this sort of number crunching really should be on the μP chip right along with the regular integer ALU. Off-chip floating-point crunchers are only as efficient as on-chip units in situations where you want to pass whole blocks of data off chip for concurrent processing. When the number-crunching instructions are interspersed in the flow of code, obviously it is better to have the floating-point unit on the μP.

DSP chips are the most extreme case of high-performance number crunching. New floating-point DSP devices like the NEC 77230, AT&T DSP32, TI 320C30, and Motorola 96001/2 have, or will have, their very fast (single-cycle) 32-bit floating-point units on chip. Likewise, some of the most efficient new RISC μPs such as the Intergraph Clipper and the Motorola 88000 have their floating-point units on chip (though they won't be single-cycle devices like the DSP floating-point chips). Of all these, the forthcoming Motorola 96001/2 DSP seems the most impressive: It is supposed to have 75-nsec single-cycle floating-point capability on chip. (Its debut is scheduled for later this year.)

Functions that set platform cost/performance

The functions in the three tables following number crunching—interrupt (**Table 1E**), DMA (**Table 1F**), memory and bus control (**Table 1G**)—orchestrate the dynamics of the computer system. They play key roles in determining cost/performance benchmarks, as you can tell by reading the descriptive paragraphs that introduce each one.

These functions are the ones most likely to be tightly integrated in the platform chip sets of **Table 2.** Such functions will be increasingly critical for the new RISC μP systems, and their added cost and complexity may largely offset the gains in RISC CPU simplicity. For example, to keep up with the ever-faster cycle times of RISC chips as clock speeds reach 50 MHz and beyond, the memory-controller function may end up as multilayered caches. Remember that all RISC chips are 32 bits and thus have inherently large memory spaces that will demand caches for economy.

Firmware now intrinsic part of support

Every recent announcement of RISC μP or IBM-clone platforms has given near-equal billing to the third-party firmware and software that you can buy to go along with it. **Table 1H**'s first listing, BIOS firmware for IBM PC and PS/2 clones, serves as a good example of why such firmware and software is so important.

First of all, because modern μP support chips have numerous internal configuration-control registers that need to be set up during initialization, a user really needs the associated BIOS to use the chips. Another reason is that, because the platforms must be 100% compatible with the IBM systems they are cloning, they need a "guaranteed-compatible" BIOS. Further, users want a BIOS that has so far withstood the legal test of IBM vs the cloners.

Will glue ever entirely disappear?

Although designers have expended a great deal of effort trying to eliminate the need for the functions listed in **Table 1I,** the need for SSI and MSI glue persists and persists. In fact, there are now so many devices in this category—and new ones continue to appear—that a 10-page table wouldn't even cover them all. Designers have made great strides in providing these functions in user-programmable gate arrays, though. To represent this trend, **Table 1I** lists two of the many gate-array possibilities; the devices are from Xilinx and Texas Instruments.

The high-integration chip sets in **Table 2** may well portend the future for μP support chips. In contrast to the bus-oriented support chips of previous EDN μP support-chip directories, the chips in **Table 2** take compatibility way up to the computing-platform level. The chips do represent an orderly evolution, however; most are built from ASIC libraries of the support chips they're replacing. **Table 2** indicates which functions the new chips include.

The high-integration chips are as much a result of market trends as they are of VLSI progress: Certain computing configurations, or platforms, have engendered unprecedented mass popularity. The μP behind the first listing of **Table 2**—the Z80—justifies high-integration support because it has the widest customer base of any 8-bit μP and its use continues to grow.

The μP behind the other listings—the 8086 and its siblings—justifies high-integration support because of the well-known IBM PC marketing phenomenon. Granted, the personal-computer market has nurtured the IBM-oriented platforms, but some industry observers claim that the platforms' use is expanding into OEM areas. Thanks to the economies of scale and widespread grass-roots hardware and software support, people are considering the platforms for applications like industrial instrumentation and control. IBM's intention to

Manufacturers of μP support chips

For more information on μP support chips such as those included in this directory, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request Service. Abbreviations in parentheses after some companies conform to the ones used in the directory. Note that there is also a separate index that indicates which categories of chips each manufacturer makes.

Adaptek
691 S Milpitas Blvd
Milpitas, CA 95035
(408) 945-8600
Circle No 550

Advanced Micro Devices (AMD)
901 Thompson Pl
Sunnyvale, CA 94088
(408) 732-2400
Circle No 551

Altera
3525 Monroe St
Santa Clara, CA 95051
(408) 984-2800
Circle No 552

Analog Devices
Box 280
Norwood, MA 02062
(617) 329-4700
Circle No 553

AT&T Microelectronics
Dept 203130
555 Union Blvd
Allentown, PA 18103
(800) 372-2447
Circle No 554

Austek
444 Castro St, Suite 1020
Mountain View, CA 94041
(415) 960-1315
Circle No 555

California Micro Devices
2000 W 14th St
Tempe, AZ 85281
(602) 968-4431
Circle No 556

Calmos
20 Edgewater St
Kanata, Ontario, Canada K2L 1V8
(613) 836-4501
Circle No 557

Chips & Technologies Inc (C&T)
3050 Zanker Rd
San Jose, CA 95134
(408) 434-0600
Circle No 558

Cirrus Logic Inc
1463 Centre Pointe Dr
Milpitas, CA 95035
(408) 945-8300
Circle No 559

Crystal Semiconductor Corp
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Austin, TX 78760
(512) 445-7222
Circle No 560

Cybernetic Micro Systems
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San Gregorio, CA 94074
(415) 726-3000
Circle No 561

Cypress Semiconductor
3901 N First St
San Jose, CA 95134
(408) 943-2666
Circle No 562

Dallas Semiconductor
4350 Beltwood Parkway
Dallas, TX 75244
(214) 450-0400
Circle No 563

Erso (Div of ITRI, Taiwan)
2950 Scott Blvd
Santa Clara, CA 95054
(408) 727-1280
Circle No 564

Exar-Excel
450 National Ave
Mountain View, CA 94043
(415) 962-3874
Circle No 565

Eyring Research
1455 W 820 North
Provo, UT 84601
(801) 375-2434
Circle No 566

Faraday Electronics Inc (WD)
746 N Mary Ave
Sunnyvale, CA 94086
(408) 749-1900
Circle No 567

Fujitsu Microelectronics Inc
3320 Scott Blvd
Santa Clara, CA 95054
(408) 727-1700
Circle No 568

G-2 Inc (LSI Logic)
1655 McCarthy Blvd
Milpitas, CA 95035
(408) 943-0224
Circle No 569

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Cupertino, CA 95014
(408) 996-5000
Circle No 570

GE-RCA
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(201) 685-7676
Circle No 571

Gould Semiconductors (AMI)
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Santa Clara, CA 95051
(401) 246-0330
Circle No 572

Harris Semiconductor
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Melbourne, FL 32901
(305) 724-7000
Circle No 573

Hitachi America Ltd
2210 O'Toole Ave
San Jose, CA 95131
(408) 435-8300
Circle No 574

Hughes Aircraft Co
Solid State Products Div
500 Superior Ave
Newport Beach, CA 92663
(714) 759-2942
Circle No 575

Industrial Programming Inc (IPI)
100 Jericho Quadrangle
Jericho, NY 11753
(516) 938-6600
Circle No 576

Integrated Device Technology Inc (IDT)
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Santa Clara, CA 95051
(408) 727-6116
Circle No 577

Intel Corp
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Santa Clara, CA 95052
(408) 987-8080
Circle No 578

Intel Corp
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Chandler, AZ 85226
(602) 961-8051
Circle No 579

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Circle No 580

Ixys
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San Jose, CA 95131
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Circle No 581

JMI Software Consultants Inc
Box 481
Springhouse, PA 19477
(215) 628-0846
Circle No 582

Linear Technology Corp
1630 McCarthy Blvd
Milpitas, CA 95035
(408) 432-1900
Circle No 583

Logic Devices Inc
628 E Evelyn Ave
Sunnyvale, CA 94086
(408) 720-8630
Circle No 584

LSI Logic Corp
1551 McCarthy Blvd
Milpitas, CA 95035
(408) 433-8000
Circle No 585

Box continued on pg 142

It is ironic that each step toward more user-interface simplicity requires greater sophistication of the graphics-system chips.

Manufacturers of µP support chips (Continued)

Maxim Integrated Products
510 N Pastoria Ave
Sunnyvale, CA 94086
(408) 737-7600
Circle No 586

Micro Computer Control (MCC)
Box 275
Hopewell, NJ 08525
(609) 466-1751
Circle No 587

Microchip Technology Inc
2355 W Chandler Blvd
Chandler, AZ 85224
(602) 345-3287
Circle No 588

Microware Systems
1900 NW 114 St
Des Moines, IA 50322
(512) 224-1929
Circle No 589

Mitsubishi Electronics America Inc
1050 Arques Ave
Sunnyvale, CA 94086
(408) 730-5900
Circle No 590

Motorola Integrated Circuits
3501 Ed Bluestein Blvd
Austin, TX 78721
(512) 928-6000
Circle No 591

Motorola Microprocessor Products Group
Highway 290 W at William Cannon (Oak Hill)
Austin, TX 78762
(512) 440-2000
Circle No 592

National Semiconductor Corp
2900 Semiconductor Dr
Santa Clara, CA 95052
(408) 721-5000
Circle No 593

NCR Corp
2001 Danfield Ct
Fort Collins, CO 80525
(303) 226-9500
Circle No 594

NCR Microelectronics Div
1635 Aeroplaza Dr
Colorado Springs, CO 80916
(303) 596-5612
Circle No 595

NEC Microcomputer Div
1 Natick Executive Park
Natick, MA 01760
(617) 655-8833
Circle No 596

NEC (US Headquarters)
401 Ellis St
Mountain View, CA 94043
(415) 960-60001
Circle No 597

Nitsume
3295 Scott Blvd, Suite 100
Santa Clara, CA 95054
(408) 748-0420
Circle No 598

Oki Semiconductor Inc
650 N Mary Ave
Sunnyvale, CA 94086
(408) 720-1900
Circle No 599

Paradise Systems Inc
217 E Grand Ave
South San Francisco, CA 94080
(415) 588-6000
Circle No 600

Performance Semiconductor Corp
610 E Weddell Dr
Sunnyvale, CA 94089
(408) 734-9000
Circle No 601

Phoenix Technologies Ltd
320 Norwood Park S
Norwood, MA 02062
(617) 769-7020
Circle No 602

Ready Systems
Box 61029
Palo Alto, CA 94306
(415) 326-2950
Circle No 603

Rockwell International
Microelectronic Devices Div
4311 Jamboree Rd
Newport Beach, CA 92660
(714) 833-4700
Circle No 604

SGS-Thompson
1310 Electronic Dr
Carrollton, TX 75006
(214) 466-6000
Circle No 605

Siemens AG
Components Group
Balanstrasse 73
Postfach 80 17 09
8000 Munich 80, West Germany
(089) 2340
Circle No 606

license its PS/2 architecture should also encourage wider use.

What lies ahead for this high-integration trend? There are indications that similar high-integration chip sets will come along to support the new RISC computers. No one should be surprised if this happens, as the very simplicity of the RISC chips begs for such bolstering.

Peripherals need VLSI for control

The controllers of **Table 3** are not as susceptible to integration as the other support functions in the directory, the reason being that they are closely associated with the special demands of the peripheral devices they control. Most of the devices being controlled are not semiconductor devices and therefore represent a more difficult marriage to the core µP system. Some, like disk drives, are complex electromechanical mechanisms. Others, like CRTs and LCD displays, though electronic, are thin-film electrochemical in nature. Still others, like motors and solenoids, are brute-force motion producers. Finally, some, like keyboards, can be just simple, primitive mechanical devices.

The most critical of the **Table 3** functions as far as performance is concerned are the disk-drive controllers of **Table 3A** and the CRT graphic-system controllers of **Table 3C.** Due to the advent of the 32-bit µP, demands on disk drives are escalating. It's up to the disk-drive controller to see that the large blocks of virtual memory are accessed fast enough that the memory does indeed seem virtual to the user.

The demands on CRT graphic systems may be even

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2191 Laurelwood Rd
Santa Clara, CA 95054
(408) 980-4500
Circle No 607

Sierra Semiconductor
2075 N Capitol Ave
San Jose, CA 95123
(408) 263-9300
Circle No 608

Signetics (Philips)
811 E Arques Ave
Sunnyvale, CA 94086
(408) 739-7700
Circle No 609

Silicon Systems
14351 Myford Rd
Tustin, CA 92680
(714) 731-7110
Circle No 610

Siliconix
2201 Laurelwood Rd
Santa Clara, CA 95054
(408) 988-8000
Circle No 611

Software Components Group
4655 Old Ironsides Dr, Suite 370
Santa Clara, CA 95054
(408) 727-0707
Circle No 612

Sprague Electric Co
115 NE Cutoff
Worcester, MA 01606
(617) 853-5000
Circle No 613

Standard Microsystems Corp (SMC)
35 Marcus Blvd
Hauppauge, NY 11788
(516) 273-3100
Circle No 614

Texas Instruments Inc (TI)
MOS Microcomputers
Box 1443
Houston, TX 77001
(713) 879-2000
Circle No 615

Toshiba America Inc
2692 Dow Ave
Tustin, CA 92680
(714) 832-6300
Circle No 616

TRW Electronic Components
Box 2472
La Jolla, CA 92038
(619) 457-1000
Circle No 617

United Microelectronics Corp (UMC)
Tung Hwa N Rd, 9th Fl, No 201-26
Taipei, Taiwan
Circle No 618

VLSI Technology Inc
8375 S River Parkway
Tempe, AZ 85284
(602) 752-8574
Circle No 619

Waferscale Integration Inc
47280 Kato Rd
Fremont, CA 94538
(415) 656-5400
Circle No 620

Weitek
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Sunnyvale, CA 94086
(408) 738-8400
Circle No 621

Western Design Center Inc (WDC)
2166 E Brown Rd
Mesa, AZ 85203
(602) 962-4545
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Western Digital (WD)
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Irvine, CA 92714
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greater, however, for the graphic system is what the end customer sees. It is ironic that each step towards more user-interface simplicity requires greater sophistication of the graphics-system chips. It takes a great deal of computing power to deliver the multicolored, multiwindowed, friendly 3D animations that customers are beginning to expect from CRTs.

Microprocessor controllers reach 32 bits

Finally, in the last of the tables, **Table 4,** you'll find μP controllers representing the so-called "software ASIC" approach. These chips are inherently highly integrated units; they typically contain not only core μPs but many other support functions as well—I/O ports, for example, and timers, interrupts, and memory controllers. Some also have ADCs and DACs and pulse-width outputs for analog interfacing and motor control. You'll even find 32-bit controllers suitable for laser-printer raster control.

Of course the directory tables hold plenty of additional information besides what you've read about in this introduction. Our purpose has been to tell you of trends and other salient features that you might otherwise overlook—and to whet your appetite. An index of support chips and their manufacturers follows; the directory tables begin on pg 146. **EDN**

Article Interest Quotient (Circle One)
High 485 Medium 486 Low 487

SUPPORT-CHIP MANUFACTURER/PRODUCT LISTING

THIS LISTING PROVIDES A GUIDE TO THE SUPPLIERS OF DEVICES MENTIONED IN THE DIRECTORY TABLES 1A THROUGH 4.

	PARALLEL I/O PORTS	SERIAL I/O PORTS	TIMERS, EVENT COUNTERS, CLOCKS	NUMBER CRUNCHERS	INTERRUPT CONTROLLERS	DMA CONTROLLERS	MEMORY AND BUS CONTROLLERS	SYSTEM FIRMWARE	SYSTEM GLUE	COMBO CHIPS, CHIP SETS	DISK CONTROLLERS	SERIAL TAPE CONTROLLERS	CRT CONTROLLERS, GRAPHICS GENERATORS	KEYBOARD AND NON-CRT DISPLAY INTERFACES	POWER DRIVERS AND CONTROLLERS	μP AND μP-LIKE CHIPS	
SUPPLIER	1A	1B	1C	1D	1E	1F	1G	1H	1I	2	3A	3B	3C	3D	3E	4	ASIC CELLS?
ADAPTEK	●										●						YES
ALTERA									●								BY USER
AMD	●		●	●	●	●	●		●		●		●	●		●	YES
ANALOG DEVICES				●												●	N/A
AT&T			●	●		●	●										N/A
AUSTEK							●										N/A
CALIFORNIA MICRO DEVICES (EX GTE)		●														●	YES
CALMOS	●	●	●	●	●	●	●		●								YES
CHIPS & TECHNOLOGIES	●									●							YES
CIRRUS LOGIC	●	●	●			●	●				●		●				YES
CRYSTAL SEMICONDUCTOR		●															YES
CYBERNETIC MICRO SYSTEMS	●	●	●											●		●	VIA FIRMWARE
CYPRESS SEMICONDUCTOR	●			●					●								
DALLAS SEMICONDUCTOR	●	●	●		●		●		●								"CLOSED" LIBRARIES
ERSO										●							YES
EXAR-EXCEL		●							●								N/A
EYRING								●									—
FARADAY (WD)										●							YES
FUJITSU	●		●	●	●	●				●			●			●	YES
G-2 (LSI LOGIC)										●							YES
GE-INTERSIL		●	●	●										●			YES
GE-RCA	●	●	●	●	●	●	●		●	●	●		●	●		●	YES
GOULD (AMI)		●					●				●		●	●			YES
HARRIS	●	●	●		●		●		●	●						●	YES
HITACHI							●			●			●			●	N/A
HUGHES		●		●	●		●	●	●							●	YES
INDUSTRIAL PROGRAMMING								●									—
INTEGRATED DEVICE TECHNOLOGY	●	●		●			●		●								YES
INTEL	●	●	●	●	●	●	●	●		●	●		●			●	YES
INTERNATIONAL RECTIFIER															●		N/A
IXYS	●	●													●		N/A
JMI SOFTWARE CONSULTANTS								●									—
LINEAR TECHNOLOGY		●															N/A
LOGIC DEVICES	●			●													
LSI LOGIC		●	●		●	●	●						●			●	YES (G-2)
MAXIM		●	●											●			N/A
MICRO COMPUTER CONTROL								●									—

SUPPLIER	PARALLEL I/O PORTS 1A	SERIAL I/O PORTS 1B	TIMERS, EVENT COUNTERS, CLOCKS 1C	NUMBER CRUNCHERS 1D	INTERRUPT CONTROLLERS 1E	DMA CONTROLLERS 1F	MEMORY AND BUS CONTROLLERS 1G	SYSTEM FIRMWARE 1H	SYSTEM GLUE 1I	COMBO CHIPS, CHIP SETS 2	DISK CONTROLLERS 3A	SERIAL TAPE CONTROLLERS 3B	CRT CONTROLLERS, GRAPHICS GENERATORS 3C	KEYBOARD AND NON-CRT DISPLAY INTERFACES 3D	POWER DRIVERS AND CONTROLLERS 3E	μP AND μP-LIKE CHIPS 4	ASIC CELLS?
MICROCHIP TECHNOLOGY	●													●		●	YES
MICROWARE SYSTEMS								●									—
MITSUBISHI																●	N/A
MOTOROLA	●	●	●	●	●	●	●		●	●	●		●		●	●	YES
NATIONAL SEMICONDUCTOR (FAIRCHILD)	●	●	●	●	●		●		●		●		●	●		●	YES
NCR	●	●	●	●		●	●		●				●			●	YES
NEC	●	●	●	●	●	●			●		●	●	●	●		●	YES
NITSUME										●							YES
OKI SEMICONDUCTOR				●						●						●	YES
PARADISE (WD)													●				N/A
PERFORMANCE SEMICONDUCTOR									●	●						●	YES
PHOENIX TECHNOLOGIES								●									—
READY SYSTEMS								●									—
ROCKWELL	●	●								●	●		●			●	N/A
SGS-THOMSON	●	●	●	●	●		●			●	●				●	●	YES
SIEMENS	●	●	●	●	●	●	●		●						●		N/A
SIERRA			●													●	YES
SIGNETICS		●				●	●		●		●		●				YES
SILICON SYSTEMS	●	●									●	●			●		YES
SILICONIX															●		YES
SOFTWARE COMPONENTS GROUP								●									—
SPRAGUE															●		N/A
STANDARD MICROSYSTEMS CORP	●	●					●				●	●	●				YES
TEXAS INSTRUMENTS	●	●	●		●		●		●				●		●	●	YES
TOSHIBA	●	●	●		●	●			●				●			●	YES
TRW ELECTRONIC COMPONENTS				●					●								YES
UNITED MICROELECTRONICS		●		●			●		●								YES
VLSI TECHNOLOGY	●	●	●	●	●	●	●		●	●	●		●			●	YES
WAFERSCALE				●					●								YES
WEITEK				●													YES
WESTERN DESIGN CENTER	●	●	●						●	●	●		●			●	YES
WESTERN DIGITAL		●									●		●				N/A
XILINX									●								YES
ZILOG	●	●	●	●	●	●	●		●	●	●		●			●	YES
ZYMOS										●							YES

NOTES: — = NOT APPLICABLE
N/A = INFORMATION NOT AVAILABLE

TABLE GROUP 1—SUBSYSTEM SUPPORT CHIPS

1A PARALLEL I/O PORTS

TYPICALLY HAVE AT LEAST TWO 8-BIT PORTS WITH LATCHES AND TWO HANDSHAKING LINES PER PORT FOR INTERFACING TO PERIPHERALS. IN SOME DEVICES, THE HOST μP CAN USE INTERNAL CONTROL REGISTERS TO SET UP BIT LINES AS INPUTS OR OUTPUTS. TREND TOWARDS STANDARDIZATION WITH SCSI BUS BEING ONE EXAMPLE. DEPENDING UPON VIEWPOINT IBM'S MICRO CHANNEL WHEN USED FOR ADDING IN FUNCTIONS MIGHT ALSO BE CONSIDERED AN EXAMPLE.

μP BUS COMPATIBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS				TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
				PORT 1	PORT 2	PORT 3	PORT 4			
8086 68000 FAMILIES (8 OR 16 BITS)	ADAPTEK	6250	3M, 5M BYTES/SEC 20-MHz CLOCK	B+1 (SCSI)	—	—	—	CMOS 5V 68-LEAD PLCC	$20 (1k QTY)	SCSI BUS PROTOCOL CONTROLLER, INITIATOR OR TARGET. SYNCHRONOUS OR ASYNCHRONOUS WITH 20M-BYTE/SEC DMA TO MEMORY (16-BIT BUS).
GENERAL 8, 16 BITS	FUJITSU	87030 87031 (SPC)	4M BYTES/SEC	8 BITS SCSI OUT	8 BITS SCSI IN	—	—	CMOS 5V 88-PIN PGA 100-LEAD FLAT PACK	$21 (1k QTY)	SCSI BUS PROTOCOL CONTROLLER. SYNCHRONOUS. CAN BE INITIATOR OR TARGET (I.E., EITHER I/O OR HOST ADAPTER). 8-BYTE FIFO, 24-BIT TRANSFER BYTE COUNTER, DMA. SINGLE-ENDED AND/OR DIFFERENTIAL.
		87033	5M BYTES/SEC	8 BITS BIDIRECTIONAL WITH DRIVERS	—	—	—	68-LEAD PLCC	$13 (1k QTY) SAMPLES	
GENERAL 8, 16 BITS	FUJITSU	89351	2M BYTES/SEC	8 BITS SCSI OUT	8 BITS SCSI IN	—	—	CMOS 64-PIN DIP 64-LEAD FLAT PACK	$5 (1k QTY)	SCSI BUS PROTOCOL CONTROLLER, ASYNCHRONOUS. CAN BE INITIATOR OR TARGET (I.E., EITHER I/O OR HOST ADAPTER). 8-BYTE FIFO, 24-BIT TRANSFER BYTE COUNTER, DMA. SINGLE-ENDED AND/OR DIFFERENTIAL.
		89352	2M BYTES/SEC	8 BITS BIDIRECTIONAL WITH DRIVERS	—	—	—	48-PIN DIP 48-LEAD FLAT	$6	
GENERAL	SILICON SYSTEMS (SSI)	32B450A 32C451	ASYNCH TO 2M BPS	8+1 BITS	—	—	—	CMOS 5V 52-LEAD 44-LEAD PLCC	$16.65 $17.15 SAMPLES	SCSI BUS CONTROLLER INITIATE/ TARGET MODES, INTERNAL DRIVERS. DUAL-PORT BUFFER CONTROLLER AND 8-BIT μP INTERFACE.
Z80 8086	SMC	82C11	—	8 BITS	—	—	—	CMOS 40-PIN DIP	$3.30	PRINTER ADAPTER INTERFACE FOR CENTRONICS PARALLEL HIGH DRIVE. 2.6 mA SOURCE, 24 mA SINK.
GENERAL	ZILOG	5380	ASYNCH TO 1.5M BPS	8+P=9 (PARITY)	—	—	—	CMOS 5V 40-PIN DIP 44-LEAD PLCC	$12.71 SAMPLES	SCSI BUS (ANSI X3T9.2) CONTROLLER. SUPPORTS INITIATOR AND TARGET ROLES, DMA, ARBITRATION. SCSI-LEVEL 48 mA DRIVERS.
Z80	TOSHIBA ZILOG	Z80 PIO, Z84C20	DC TO 4, 6, 8-MHz μP CLOCK	8+2 HANDSHAKE	8+2 HANDSHAKE	—	—	CMOS 5V 40-PIN 44-PIN FLAT PACK	$1.75	CMOS VERSION OF NMOS Z8420. 2 mA AT 4 MHz AND LESS THAN 10 μA AT 5V POWER DOWN (CLOCK STOPPED).
Z80	ZILOG	84C90 SPCT	8, 10 MHz	8+2 HANDSHAKE	8+2 HANDSHAKE	8	—	CMOS 84-LEAD PLCC 80-LEAD QUAD FLAT PACK	$14.30	HIGH-INTEGRATION COMBO DEVICE THAT, IN ADDITION TO THESE 84C20 PORTS, ALSO INCLUDES SERIAL PORTS AND TIMERS (SEE LISTINGS IN **TABLES 1B**, **1C**, AND **2**).

— = NOT APPLICABLE
NA = NOT AVAILABLE
THE VOLUME OF AVAILABLE SUPPORT CHIPS PREVENTS INCLUSION OF ALL APPROPRIATE DEVICES IN THIS DIRECTORY. FOR MORE INFORMATION, REFER TO THE MANUFACTURER/PRODUCT LISTING AT THE BEGINNING OF THE DIRECTORY.

1B SERIAL I/O PORTS

ORIGINALLY MAINLY ASYNCHRONOUS TELETYPE UARTS, THESE DEVICES NOW SERVICE AN INCREASING VARIETY OF COMPLEX ASYNCHRONOUS AND SYNCHRONOUS PROTOCOLS, RANGING FROM THOSE FOR SIMPLE 3-WIRE SYSTEMS TO THOSE FOR ELABORATE COMMERCIAL, INDUSTRIAL, AND MILITARY NETWORKS. (LANS AND TELECOM NETWORKS COULD BE CONSIDERED EXTENSION OF THIS CATEGORY.)

μP BUS COMPATIBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS				TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
				SDLC	HDLC	ADCCP	BISYNC			
GENERAL	SMC	78C802 78C804 78C808	19.2k BPS	—	—	—	—	CMOS 5V 40-PIN DIP, 44-LEAD PLCC, 48-PIN DIP, 44-LEAD PLCC, 68-PIN PLCC	$13 $21 $35	CMOS VERSIONS OF MULTIPLE UARTS ON SINGLE CHIPS. 78C02 IS DUAL UART, 78C04 IS QUAD UART, AND 78C08 IS OCTAL UART.
GENERAL	SMC	9064	2.35M BPS	—	—	—	—	CMOS 5V 40-PIN DIP 44-LEAD PLCC	$15	IBM 3270 INTERFACE CONTROLLER. CMOS VERSION OF 9004.
Z80	TOSHIBA ZILOG	Z80C SIO Z84C40	DC TO 4, 6, 8 MHz, 800k BAUD	YES	YES	—	YES	CMOS 5V 40-PIN 44-PIN FLAT PACK	$3.50	CMOS VERSION OF NMOS Z844X. 1/10TH OPERATING POWER AND LESS THAN 10 μA WHEN POWERED DOWN (CLOCK STOPPED). ALSO ASYNCHRONOUS.
Z80	ZILOG	84C90 SPCT	8, 10 MHz	YES	YES	—	YES	CMOS 5V 84-LEAD PLCC 80-LEAD QUAD FLAT PACK	$14.30	HIGH-INTEGRATION COMBO DEVICE THAT, IN ADDITION TO THESE 84C40 SERIAL FUNCTIONS, ALSO INCLUDES PARALLEL PORTS AND TIMERS (SEE LISTINGS IN **TABLES 1A**, **1C**, AND **2**).
GENERAL (10 BITS)	NATIONAL	DP 8340 DP 8341	2.3587M BPS (28-MHz CLOCK)	— —	— —	— —	— —	BIPOLAR LOW-NOISE SCHOTTKY 24-PIN 28-PIN PCC	$40 PER SET	ENCODER/DECODER PAIR MEET IBM 3270 BIPHASE INFORMATION DISPLAY STANDARD AT 2.3587M BPS.

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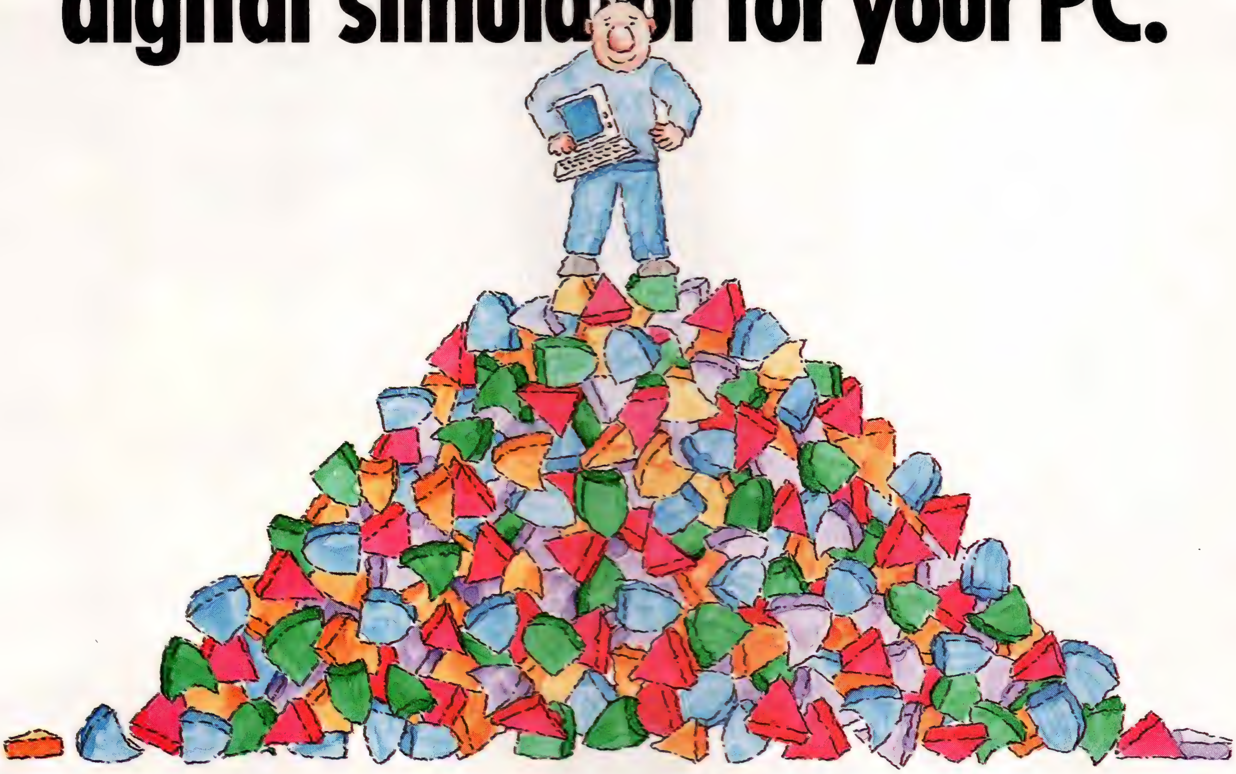

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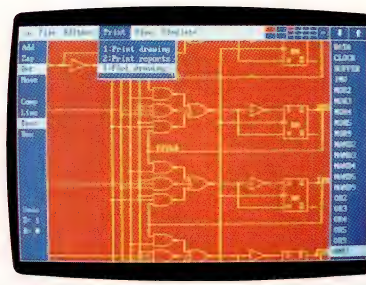

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1B SERIAL I/O PORTS *(continued)*

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: SDLC	HDLC	ADCCP	BISYNC	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL (8-BITS)	NATIONAL	DP 8342 DP 8343	3.5M BPS (28-MHz CLOCK)	— —	— —	— —	— —	BIPOLAR LOW-POWER SCHOTTKY 24-PIN 28-PIN PCC	$30 PER SET	GENERAL-PURPOSE HIGH-SPEED MANCHESTER ENCODER/ DECODER PAIR.
GENERAL (8-BIT)	NATIONAL	DP 8344	2.3587M AND 1.0M BPS	—	—	—	—	CMOS 5V 84-PIN PCC	$50	IBM 3270, 3299, 5259, ETC., PROTOCOL, PROGRAMMABLE ENCODER/DECODER (μP).
8080 8086 8088	SILICON SYSTEMS (SSI)	73M450	56k BAUD	—	—	—	—	CMOS 40-PIN DIP, 44-LEAD PLCC	$11.10 SAMPLES	UART (SIMILAR TO 8250A)
8048 8051 (IBM PC)	SILICON SYSTEMS (SSI)	73K212 221 222 224 322 212U 221U 222U	1200 BPS AND 2400 BPS	—	—	—	—	CMOS 22-PIN DIP 28-LEAD PLCC 40-PIN DIP 44-LEAD PLCC	$22 TO $52.64 SAMPLES	K-SERIES FAMILY OF SINGLE-CHIP MODEMS, 1200 AND 2400 BPS, PINOUT AND REGISTER COMPATIBLE, WORLDWIDE STANDARDS. U SUFFIX INDICATES INTEGRAL UART. APPLICATION SOFTWARE, PC CARDS.
68000	CIRRUS LOGIC	CD180	38.4k BPS, ASYNCH ON ALL 8 CHANNELS	—	—	—	—	CMOS 5V 84-PIN PLCC	$80	EIGHT CHANNELS WITH ON-CHIP FIFOs, AUTOMATIC FLOW CONTROL AND ADDED INTELLIGENCE TO HANDLE MULTIPLE-CHANNEL INTERRUPTS.

— = NOT APPLICABLE
NA = NOT AVAILABLE
THE VOLUME OF AVAILABLE SUPPORT CHIPS PREVENTS INCLUSION OF ALL APPROPRIATE DEVICES IN THIS DIRECTORY. FOR MORE INFORMATION, REFER TO THE MANUFACTURER/PRODUCT LISTING AT THE BEGINNING OF THE DIRECTORY.

1C TIME-ORIENTED DEVICES: TIMERS, EVENT COUNTERS, AND CLOCKS

TIMERS PROVIDE ONE OR MORE UP- OR DOWN-COUNTING REGISTERS THAT CAN BE PRESET VIA PROGRAM CONTROL BY μP AND THEN COUNT OUT CLOCK CYCLES AND FLAG μP BY INTERRUPT WHEN DONE. SOME COUNT PULSES (EVENTS) ON INPUT LINE. ALSO INCLUDED ARE OTHER TIMING FUNCTIONS SUCH AS SYSTEM CLOCKS AND REAL-TIME CLOCKS.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: TIMER 1 (BITS)	TIMER 2 (BITS)	TIMER 3 (BITS)	TIMER 4 (BITS)	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
Z80	TOSHIBA ZILOG	Z80 CTC Z84C30	DC-4, 6, 8 MHz	16	16	16	16	CMOS 5V 40-PIN 44-PIN FLAT PACK	$1.25	CMOS VERSION OF NMOS Z8430. 1/10TH OPERATING POWER AND LESS THAN 10 μA WHEN POWERED DOWN (CLOCK STOPPED).
Z80	ZILOG	84C90 SPCT	8, 10 MHz	8	8	8	8	CMOS 5V 84-LEAD PLCC 80-LEAD QUAD FLAT PACK	$14.30	HIGH-INTEGRATION COMBO DEVICE THAT, IN ADDITION TO THESE 84C30 TIMERS, ALSO INCLUDES PARALLEL AND SERIAL PORTS (SEE LISTINGS IN **TABLES 1A**, **1C**, AND **2**).
SPI SERIAL BUS	RCA MOTOROLA	68HC68T1	32 kHz (SEC, MIN, HR, DAY, MO, YR)	REAL-TIME CLOCK	—	—	—	CMOS 5V 16-, 20-PIN SMALL OUTLINE, DIP	$3.45	REAL-TIME CLOCK, INTERFACES OVER "SPI" STD ECONOMY SERIAL BUS.
GENERAL (SERIAL)	HUGHES (FOR CURTIS INSTRUMENT MT. KISCO, NY)	2001 PC	DC TO 32 kHz	TO 9,999,999 EVENTS OR 99,999.99 HRS	—	—	—	CMOS 5V HYBRID DIP	$45	SOLID-STATE VERSION OF CHEMICAL COULOMB LAPSE-TIME METER FOR MAINTENANCE MONITORING. 2-TERMINAL INPUT AND 3-TERMINAL SERIAL READ-OUT MEETS MIL SPECS.
GENERAL	AMD	2971A	100 MHz (OUTPUT RESOLUTION)	—	—	—	—	BIPOLAR 24-PIN CERAMIC DIP	$15	EVENT GENERATOR FUSE PROGRAMMABLE STATE MACHINE AND PLL.

— = NOT APPLICABLE
NA = NOT AVAILABLE
THE VOLUME OF AVAILABLE SUPPORT CHIPS PREVENTS INCLUSION OF ALL APPROPRIATE DEVICES IN THIS DIRECTORY. FOR MORE INFORMATION, REFER TO THE MANUFACTURER/PRODUCT LISTING AT THE BEGINNING OF THE DIRECTORY.

1D NUMBER CRUNCHERS

PROVIDE HARDWIRED OR FIRMWARE IMPLEMENTATION OF DATA-MANIPULATION INSTRUCTIONS THAT ARE OTHERWISE DIFFICULT TO PROGRAM AND SLOW TO ACCOMPLISH WITH MAIN μP. INCLUDES INTEGER AND FLOATING-POINT MULTIPLICATION, TRIG FUNCTIONS, AND SPECIAL ALGORITHMS SUCH AS ENCRYPTION, ETC.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: MATH	TRIG	FL PT	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
80386	WEITEK	1167	16, 20 MHz	×, ÷, +, − ABS VAL, COMPARE	SUPPORTED BY RUN-TIME LIBRARY	YES	NMOS 5V 121-PIN PGA	$480 (16 MHz) $630 (20 MHz)	3-CHIP SET MOUNTED ON DAUGHTER BOARD THAT PLUGS INTO SUPERSET OF 80387 SOCKET. C, FORTRAN, PASCAL COMPILERS AVAILABLE. WITH 80386 DELIVERS 4.6 WHETSTONES AT 20 MHz.
GENERAL (68030, 80386, SPARC, ETC.)	TI	74ACT-8847	10 MHz (33M FLOPS)	+, −, ×, ÷, SQUARE ROOT, LOGIC	NO	+, −, ×, ÷	CMOS 5V (STATIC) 209-PIN PGA	$600 SAMPLES	IEEE 754. COMBINES MULTIPLIER AND ALU. SUPERSET OF 8837. CAN DO SUM-OF-PRODUCTS, PRODUCT-OF-SUMS.

Continued on pg 153

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1D NUMBER CRUNCHERS *(continued)*

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS			TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
				MATH	TRIG	FL PT			
32100 GENERAL	AT&T ZILOG	32106	10 MHz 14 MHz 18 MHz	+, −, ×, ÷, SQUARE ROOT, ETC.	NO	YES 32, 64, 80 BITS	CMOS 5V 125-PIN PGA	$120	IEEE-754 COPROCESSOR FOR 32100 μP, CAN BE PERIPHERAL FOR OTHERS.
32200 GENERAL	AT&T ZILOG	32206	24 MHz	+, −, ×, ÷, SQUARE ROOT, ETC.	YES SINE, COS, ARCTAN, Pi	YES 32, 64, 80 BITS (4M WHET-STONES)	CMOS 5V 125-PIN PGA	$400	UPWARD EXTENSION OF 32106. EIGHT 80-BIT USER REGISTERS. HANDLES INTEGER, DEC TO FLOATING-POINT CONVERSIONS.
GENERAL	AMD	29C325	100 nSEC	×, ÷, +, −	NO	YES	CMOS 144-PIN PGA	$155	SUPPORTS IEEE, DEC FORMATS; SINGLE-CYCLE OPERATION FOR +, −, ×; NEWTON-RAPHSON ALGORITHM FOR ÷.
GENERAL	AMD	29C323	55 nSEC	× (32×32)	NO	NO	CMOS 168-PIN PGA	$119	3-BUS MULTIPLIER; OPTIONAL FOR PIPELINED AND FLOW-THROUGH MODE; MASTER/SLAVE AND ERROR CHECKING.

— = NOT APPLICABLE
NA = NOT AVAILABLE
THE VOLUME OF AVAILABLE SUPPORT CHIPS PREVENTS INCLUSION OF ALL APPROPRIATE DEVICES IN THIS DIRECTORY. FOR MORE INFORMATION, REFER TO THE MANUFACTURER/PRODUCT LISTING AT THE BEGINNING OF THE DIRECTORY.

1E INTERRUPT CONTROLLERS

EXPAND, PRIORITIZE, AND PROVIDE INTERRUPT VECTOR ADDRESSING FOR μPs. BECAUSE OF EMPHASIS ON FAST INTERRUPT RESPONSE, TREND HAS BEEN TO INCORPORATE THIS FUNCTION ON μP AND TO EXPAND IT ON THE CHIP SETS OF **TABLE 2**.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS				TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
				PRIORITY LEVELS	EXPAND-ABLE	PROGRAM-MABLE	INTERRUPT MASKING			
8080/85 8086/88	HARRIS OKI VLSI SIEMENS	82C59A	8, 10 MHz μP CLOCK	8	YES TO 64 LEVELS	YES	YES	CMOS 5V 28-PIN PLCC	$3.70	OPERATES IN EITHER 8080/85 OR 8086/88 CALL MODE. THIS FUNCTION NOW ON HIGH-INTEGRATION CHIP SETS OF **TABLE 2**.
	NEC	71059	10 MHz						$3.10	

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NA = NOT AVAILABLE
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1F DMA CONTROLLERS

TAKE OVER μP BUSES AND ACT AS SPECIAL-PURPOSE μPs TO CONTROL ADDRESS BUS AND MOVE BLOCKS OF DATA. FUNCTIONS AS COPROCESSOR. BECAUSE DMA IS OFTEN CRITICAL TO ANOTHER CHIP'S SYSTEM-LEVEL PERFORMANCE, TREND IS TO INCORPORATE DMA ON OTHER CHIPS. NOTE THAT HERE IS SITUATION WHERE IT IS IMPORTANT TO HAVE BUS WIDTHS MATCHED TO HOST μP IF MAXIMUM PERFORMANCE IS DESIRED.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS		TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
				CHANNELS	MODES			
Z80 (8 BIT)	TOSHIBA ZILOG	Z84C10	DC TO 4, 6, 8 MHz	1	BYTE-AT-TIME, BURST, CONTINUOUS TRANSFER, SEARCH OR TRANSFER/ SEARCH	CMOS 5V 40-PIN 44-PIN FLAT PACK	$15.95 $7	CMOS VERSION OF NMOS Z8410. SUPPORTS DAISY-CHAIN INTER-RUPTS AND DMA REQUESTS. 2M BYTES/SEC.
8086/88 80286 80386 (16 BIT)	SIEMENS	82257	8 MHz	4	32 SUB CHANNELS	NMOS 5V 68-LEAD, 68-LEAD PLCC (LCC AND PGA)	$30	16-BIT BUS, FLY BY TRANSFER, COMMAND CHAINING.
		82258	8, 10 MHz	4			$100	
Z8000 GENERAL (16 BIT)	ZILOG AMD	9516A 8516 8016	4, 6 MHz	2	FLOWTHROUGH, BURST, CONTINUOUS, SEARCH, TRANSFER AND SEARCH, COMMAND CHAINING	NMOS 5V 48-PIN	$11	6.66M-BYTE/SEC TRANSFER RATE, SUPPORTS 16-BIT BUSES.
32100 GENERAL (32 BIT)	AT&T ZILOG	32104	10, 14, 18 MHz	4	CHAINING, CYCLE STEAL, BURST, MULTIWORD	CMOS 5V 133-PIN PGA	$125 ($75 PRO-MOTION SALE)	FULL 32-BIT ADDRESS AND DATA PATHS WITH ADDITIONAL 8-BIT PERIPHERAL BUS. TRANSFER RATES TO 14.4M BYTES/SEC.
3200 GENERAL (32 BIT)	AT&T	32204	24 MHz	4	CHAINING, CYCLE STEAL, BURST, MULTIWORD	CMOS 5V 133-PIN PGA	$500 SAMPLES	UPGRADE OF 32104. TRANSFER RATES TO 19.2M BYTES/SEC.

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1G MEMORY (INCLUDING VIRTUAL MEMORY AND CACHE) AND BUS CONTROLLERS (INCLUDING BACKPLANE)

THIS SECTION HAS BECOME A CATCHALL. ORIGINALLY JUST INCLUDED REFRESH EXCITATION FOR DYNAMIC MEMORIES BUT NOW INCLUDES BUS SUPPORT DEVICES FOR COMPLICATED BUSES LIKE VME AND MULTIBUS. CURRENT EMPHASIS IS ON NEEDS OF THE VERY LARGE AND HIGH-PERFORMANCE BUS SYSTEMS FOR 32-BIT μPs. SEE ALSO THE HIGH-INTEGRATION CHIP SETS IN **TABLE 2**.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS		TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
				CHANNELS, ETC	MODES, ETC			
GENERAL 16 BIT 32 BIT 64 BIT	NATIONAL	DP 8520 DP 8521 DP 8522	0 TO 30 MHz	256k BYTES 1M BYTES 4M BYTES	22-BIT PROGRAMMABLE REGISTERS	CMOS 5V 68- AND 84-PIN PCC	$18 TO $21.50 $28	PROGRAMMABLE DRAM CONTROLLER/DRIVERS. SUP-PORT DUAL PORTING AND GRAPHICS.

1G MEMORY (INCLUDING VIRTUAL MEMORY AND CACHE) AND BUS CONTROLLERS (INCLUDING BACKPLANE) *(continued)*

μP BUS COMPATIBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: CHANNELS, ETC	KEY SPECIFICATIONS: MODES, ETC	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL 16 BIT 32 BIT	NATIONAL	DP 8417 DP 8418 DP 8419	0 TO 30 MHz 70 nSEC RASIN TO CAS LOW, 500-pF LOADS	16k 64k 256k	4 MODES. AUTOMATIC OR EXTERNALLY CONTROLLED ACCESS AND REFRESH. NIBBLE/PAGE.	BIPOLAR ALS, 5V 48-PIN DIP, 68-PIN PCC	$15	256k-BIT DRAM CONTROLLER/ DRIVER TAILORED FOR 16-, 32-BIT WORDS, PLUS ERROR-CORRECTION CHECK BITS.
GENERAL	NATIONAL	DP 8428 DP 8429	0 TO 30 MHz	ALL 1M-BIT DRAMS	FOUR MODES. AUTOMATIC OR EXTERNALLY CONTROLLED ACCESS AND REFRESH, NIBBLE/PAGE MODE.	BIPOLAR ALS, 5V 52-PIN DIP, 68-PIN PCC	$19	1M-BIT DRAM CONTROLLER/ DRIVER FOR 32-BIT WORDS PLUS ERROR-CORRECTION CHECK BITS.
GENERAL	NATIONAL	DP 8420 DP 8421 DP 8422	0 TO 30 MHz	256k 1M 4M	22-BIT PROGRAMMABLE REGISTERS	CMOS 5V 68- OR 84-PIN PCC	$19 $22 $27	PROGRAMMABLE DRAM CONTROLLER/DRIVER FOR 16-, 32- AND 64-BIT WORDS. SUPPORTS DUAL PORTING.
MULTIBUS-II (ALL μPs)	VLSI TECH, INTEL	82C389 (MPC)	8, 10 MHz	MULTIBUS-II BACKPLANE (32 BITS)	STATE-MACHINE IMPLEMENTATION OF BOTH TRADITIONAL BUS FUNCTIONS AND ADVANCED FUNCTIONS SUCH AS MESSAGE PASSING (IEEE 1296)	CMOS 5V 149-PIN PGA	$145	MPC OR "MESSAGE-PASSING COPROCESSOR" IMPLEMENTS THE MULTIBUS-II PROTOCOL, AND ONE MPC IS EXPECTED TO BE ON EVERY M-II BOARD.
32100 (32 BIT)	AT&T	32101	10, 14, 18 MHz	—	TRANSLATION, RELOCATION, AND PROTECTION	CMOS 5V 125-PIN PGA	$120	MEMORY MANAGER FOR 32100 μP.
32100 (32 BIT)	AT&T	32103	10, 14, 18 MHz	—	ADDRESSES UP TO 16M BYTES DRAM, 16 OR 32 BITS, WITH REFRESH	CMOS 5V 125-PIN PGA	$55	DYNAMIC-RAM CONTROLLER.
32200 (32 BIT)	AT&T	32201	20, 24 MHz	—	INCLUDES 4k BYTES CACHE (INSTRUCTION OR DATA)	CMOS 5V 133-PIN PGA	$575 SAMPLES	MEMORY MANAGEMENT AND DATA/INSTRUCTION CACHE FOR 32200 μP.
GENERAL	AMD	95C85	12, 16 MHz	LOCAL AND SYSTEM BUSES	CONTENT-ADDRESSABLE MEMORY, INDEPENDENT OF RECORD SIZE	CMOS 5V 44-PIN PLCC	$67	SAID TO BE 300 TIMES FASTER THAN SOFTWARE FOR APPLICATIONS INVOLVING SORTING, DELETION.
GENERAL (32 BIT)	AMD	29C660	40, 35, 30 nSEC	—	DATA ERROR DETECT AND CORRECT	CMOS 5V 68-LEAD PLL	$60	32-BIT ERROR DETECTION AND CORRECTION.

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1H SYSTEM FIRMWARE

ROMABLE SOFTWARE OF INTEREST TO OEM DESIGNERS. INCLUDES OPERATING-SYSTEM KERNELS, I/O DEVICE DRIVERS (BIOS), REAL-TIME EXECUTIVES, POPULAR INTERPRETED-TYPE HIGH-LEVEL LANGUAGES, MATH SUBROUTINES, ETC. CONSIDERED PART OF DIRECTORY BECAUSE ARE USUALLY CLOSELY ASSOCIATED WITH SUPPORT CHIPS AND ARE OFTEN PURCHASED AS COMPONENTS (ROMs) BY DESIGNER.

μP BUS COMPATIBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: ROM FIRMWARE	KEY SPECIFICATIONS: RAM REQ (BYTES)	KEY SPECIFICATIONS: OTHER FEATURES	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
8088 8086 80286 80386 (PC, XT AT, PS/2 PLATFORMS)	PHOENIX	ROM BIOS	VARIES WITH TARGET PLATFORM	8k	VARIES	CUSTOMIZED FOR OEMs AND INCLUDE VGA, EGA GRAPHICS, 8042 KEYBOARD, AND MICRO CHANNEL SUPPORT.	(IN ROM OR BY CUSTOMER)	$25k–$200k UP FRONT PLUS ROYALTIES	BASIC INPUT/OUTPUT SYSTEM (BIOS) FIRMWARE FOR IBM PC AND PS/2 CLONES DEVELOPED FOR OEMs ON CONTRACT AND LICENSE BASIS, TAKING FROM 4 TO 18 MONTHS. SAID TO BE USED BY 80% OF MARKET.
680X0 FAMILY 8086 FAMILY (INCLUDING 80386) Z80 Z8002 32000 29000 1750A	READY SYSTEMS	VRTX32 ARTX	VARIES WITH TARGET PROCESSOR	8k	3k	MULTITASKING, PREEMPTIVE PRIORITY-BASED SCHEDULING, FIXED-COST SYSTEM CALLS, MINIMAL INTERRUPT DISABLE TIME. INCLUDES SEMAPHORES, FLAGS, QUEUES, AND MAILBOXES.	(BY CUSTOMER)	$100 WITH VOLUME LICENSE, $3k–$4k FOR R&D LICENSE	REAL-TIME KERNEL WITH I/O, FILE MANAGEMENT, MULTIPROCESSOR, AND DEBUG SUPPORT, COMPILER AND CASE DEVELOPMENT TOOLS. HELP FOR ADA AND REAL-TIME LINK TO UNIX. ARTX ON 1750A 68k ONLY.
68000 68010 68020 68030	EYRING RESEARCH INSTITUTE	PDOS	<30 μSEC CONTEXT SWITCH AT 25 MHz	3 TO 34k	8k+	100+ COMMANDS. FILE, MONITOR, AND DEBUG. SUPPORT FOR C, FORTRAN, PASCAL, AND MULTIPROCESSING.	(BY CUSTOMER)	$100 (SOLD VIA LICENSE)	ROMABLE REAL-TIME EXECUTIVE FOR 68000 FAMILY μPs. CROSS-DEVELOPMENT OPTIONS (90% TO VME BUS MARKET).
Z80 8080/85 8086/88 80286/386 680X0 32000 LSI-11 WE32100 DSP34010 CLIPPER 64180 ETC	JMI	C EXECUTIVE	24 μSEC CONTEXT SWITCH	5k TO 7k ×8 ON 16 MHz 68020	—	PROVIDES INTERRUPT-DRIVEN DEVELOPMENT DRIVERS AND PRIORITIZED SCHEDULING, ETC. MOSTLY IN C LANGUAGE. OPTIONAL FILE SYSTEM.	(BY CUSTOMER)	$70 (LIC)	ROMABLE SOFTWARE THAT PERMITS MULTIPLE C PROGRAMS TO RUN FROM MAIN MEMORY WITHOUT DISK. PORTABLE C LIBRARY HAS UNIX-LIKE ROUTINES FOR EMBEDDED APPLICATION. WHILE SPEED MAY SUFFER BECAUSE IN C RATHER THAN ASSEMBLY, IT IS EASILY TRANSFERRED TO NEW μPs.


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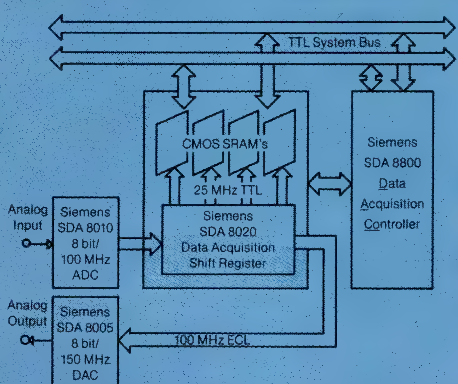

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1H SYSTEM FIRMWARE *(continued)*

μP BUS COMPATIBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: ROM FIRMWARE	RAM REQ (BYTES)	OTHER FEATURES	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
AMD 80C51	MCC	CLIB-521	VARIES WITH TARGET	1k TO 2k	0	DRIVERS FOR DUAL DATA POINTERS, WATCHDOG TIMER, SOFTWARE RESET, LOW-POWER MODE.	ROM, PROM (BY CUSTOMER)	$125	C-LANGUAGE-CALLABLE DEVICE DRIVERS FOR PARTICULAR SUPPORT FUNCTIONS ON AMD 50C521.

— = NOT APPLICABLE
NA = NOT AVAILABLE
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1I SYSTEM GLUE

THESE BUS BUFFERS, DRIVERS, TRANSCEIVERS, ADDRESS DECODERS, CONTROL LOGIC GATES, ETC, UNITE THE MAIN LSI PARTS OF A μP SYSTEM TOGETHER. LISTED IS A VERY SMALL, SOMEWHAT RANDOM, SAMPLING OF THE MANY THOUSANDS OF DEVICE TYPES AVAILABLE. FOR A MORE COMPLETE PICTURE, CONSULT STANDARD CATALOGS FOR BIPOLAR TTL, CMOS TTL, ECL LOGIC, ETC. KEEP IN MIND THAT MANY OF THESE PARTS ARE NOW ALSO IN MOST SEMICUSTOM CELL LIBRARIES. LATEST TREND IS TO SAVE VALUABLE BOARD SPACE BY ABSORBING THESE IN HIGH-INTEGRATION CHIP SETS (SEE **TABLE GROUP 2**).

μP BUS COMPATIBILITY	SUPPLIER	MODEL	KEY SPECIFICATIONS: FUNCTIONS	SPEED	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL	NATIONAL	DS 3896 DS 3897 DS 3893A	OCTAL+QUAD TRANSCEIVERS. COMPATIBLE WITH FUTURE-BUS IEEE P896 SPEC	—	BIPOLAR 20-PIN DIP AND PCC	$6 $4	BACKPLANE TRANSCEIVER LOGIC DEVICES. 1V SIGNAL SWING, <5-pF OUTPUT CAPACITANCE.
GENERAL	XILINX AMD	XC20XX XC30XX	USER-PROGRAMMABLE GATE ARRAY (1200 TO 9000 GATES)	35 MHz	CMOS PLCC PGA	$20 TO $50	CAN BE "SET UP" BY HOST μP WRITE PATTERNS INTO INTERNAL RAM THAT CONFIGURES LOGIC.
GENERAL	TI	BPAD16N8-7	USER-PROGRAMMABLE ADDRESS DECODE. 10 DEDICATED INPUTS AND 8 PRODUCT TERMS (6 TO I/O, 2 DEDICATED)	7 nSEC (MAX PROP DELAY IN-TO-OUT)	BIPOLAR 5V 20-PIN DIP, PLCC	$9.39 (1k QTY)	PLD SIAD TO BE SUITED FOR MINIMUM-DELAY SRAM ADDRESS DECODE, FROM 16 IN, 2 OUT TO 10 IN, 8 OUT.

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TABLE 2—COMBINATION CHIPS AND CHIP SETS

THESE DEVICES COMBINE SEVERAL SUPPORT AND μC SYSTEM FUNCTIONS. IN THE PAST WERE POPULAR BECAUSE THEY PERMITTED ECONOMICAL 2-CHIP SYSTEMS. NOW TREND IS TO USE VLSI ADVANCES TO COMBINE SOME SUPPORT FUNCTIONS WITH μP ITSELF AND THEN GROUP OTHERS TOGETHER ON A FEW CHIPS OF A HIGH-INTEGRATION CHIP SET. THE ADVENT OF MASS-PRODUCED PLATFORMS LIKE THE IBM PC AND PS/2 IS HAVING A PROFOUND EFFECT HERE.

μP BUS COMPATIBILITY	SUPPLIER	MODEL	SPEED	FUNCTIONS INCLUDED (KEYED TO SECTIONS OF THIS DIRECTORY) 1A	1B	1C	1D	1E	1F	1G	1H	1I	3A TO 3E	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
Z80	ZILOG	84C90 (SPCT)	8, 10 MHz	•	•	•								CMOS 5V 84-LEAD PLCC 44-LEAD QUAD FLAT PACK	$14.30	INTEGRATES SUPPLIER'S 8430 CTC, 84C4X CIO, 84C20 PIO, ETC, FOR Z80 PLATFORMS. (SEE LISTINGS IN **TABLES 1A**, **1B**, **1C** FOR COMPARISON.)
Z80 ZBUS	ZILOG	84C80/81 (GLU)	8, 10 MHz			•				•		•		CMOS 5V 68-LEAD 44-LEAD PLCC	$5.65 $4.95	COMPANION CHIP TO SUPPLIER'S 84C90. INTEGRATES SSI AND MSI "GLUE" FUNCTIONS FOR A Z80 PLATFORM.
8086/88 (PC XT, PS/2 MOD-30 PLAT-FORMS)	CHIPS & TECHNOL-OGIES	82C100	10 MHz	•		•		•	•	•		•		CMOS 5V 84-LEAD PLCC	$33	82C100 FOR BOTH 8- AND 16-BIT 8086; 82C101 FOR 8-BIT 8088.
		82C101		•		•		•	•	•		•			$26 (10k QTY)	
80286 (AT PLAT-FORM)	CHIPS & TECHNOL-OGIES	82C201	6, 8, 10 MHz			•		•		•		•		CMOS 84-LEAD PLCC	$63 (1k QTY) FOR SET	5-CHIP SET FOR MODERATE-PERFORMANCE IBM PC/AT CLONES. CMOS USED FOR COMPLEX VLSI PARTS, SCHOTTKY BIPOLAR USED FOR LESS COMPLEX PARTS THAT NEED BUFFER DRIVE.
		82C202	(10, 12.5 MHz)							•		•				
		82C202A								•		•				
		82C206				•		•	•							
		82C203	6, 8, 10 MHz							•		•		BIPOLAR 68-LEAD PLCC		
		82C204										•				
		82C205										•				
80286 (PC AT)	CHIPS & TECHNOL-OGIES	NEAT:	12 MHz 16 MHz											CMOS 5V 84-LEAD PLCC 100-PIN PLASTIC FLAT PACK	$72 $86	NEAT STANDS FOR "NEW ENHANCED AT" CHIP SET. TO BE USED IN 80286 SYSTEM.
		82C211								•		•				
		82C212								•						
		82C215								•		•				
		82C206														
80286 (PS/2 MOD-50 MOD-60)	CHIPS & TECHNOL-OGIES	82C221	10, 12, 16 MHz	•										CMOS 84-LEAD PLCC 100-PIN PLASTIC FLAT PACK	$157.10 $169.50 (1k QTY) PER SET SAMPLES	CHIP SET FOR CLONING IBM PS/2 MODEL 50 AND 60. AS IS ALL CMOS CAN BE USED WITH HARRIS 80C286 FOR LAPTOPS. INCORPORATES MICRO-CHANNEL BUS CONTROL.
		82C222								•						
		82C223							•							
		82C225										•				
		82C226		•	•											
		82C227											•			
		82C451/2														
		82C607														
80386 (AT PLAT-FORM)	CHIPS & TECHNOL-OGIES	82C301	16 MHz 20 MHz			•		•		•		•		CMOS 84-LEAD PLCC BIPOLAR 68-LEAD PLCC	$127 $140 (1k QTY)	CHIP SET FOR 80386 μP SYSTEMS BASED ON FOUR BUSES OF IBM PC/AT: LOCAL, SYSTEM MEMORY, I/O CHANNEL, AND EXPANSION (BIPOLAR DRIVERS ARE BEING REPLACED WITH CMOS).
		82C302				•				•		•				
		82A303								•		•				
		82A304								•		•				
		82A305										•				
		82A306				•				•						

TABLE 2—COMBINATION CHIPS AND CHIP SETS *(continued)*

μP BUS COMPATIBILITY	SUPPLIER	MODEL	SPEED	FUNCTIONS INCLUDED (KEYED TO SECTIONS OF THIS DIRECTORY) 1A	1B	1C	1D	1E	1F	1G	1H	1I	3A TO 3E	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
80386 (PS/2 MOD-80)	CHIPS & TECHNOL- OGIES	82C321 82C322 82C223 82C325 82C226 82C451/2 82C607	16 MHz 20 MHz	• •	 •	 •		 •	 •	 •		 • •	 • • •	CMOS 68-LEAD 84-LEAD PLCC 100-PIN 144-PIN PLASTIC FLAT PACK	$202.20 $239.50 (1k QTY) SAMPLES	BASICALLY 7-CHIP SET FOR PS/2 MODEL 80. SAID TO ALLOW MORE PERFORMANCE IN SMALLER AT-SIZE PACKAGE AND AT LOWER COST THAN IBM. CALLED "CHIPS/280." 82C321 HAS MICRO CHANNEL.
80286 (PC/AT)	ZYMOS INTEL	82230 82231	8, 10, 12 MHz			• •		• •	 •	• •		• •		CMOS 84-LEAD PLCC	$60 PER SET	2-CHIP HIGH-INTEGRATION CHIP SET FOR CONSOLIDATING SUPPORT DEVICES FOR IBM PC/AT PLATFORMS. DEVELOPMENT BOARDS AVAILABLE.
8086 80C86 V30	FARADAY (WESTERN DIGITAL)	FE2011	7.15, 9.54 MHz	•		•		•	•	•		•		CMOS 5V 132-PIN JEDEC (SURF MOUNT)	$52.75 ($31.75, 10k VOL) SAMPLES	HIGH-INTEGRATION CHIP FOR IBM PS/2 MODEL 30 CLONES. SAID TO REPLACE 100 COMPONENTS. SOCKETS FOR THROUGH-HOLE PC BOARDS.
80286	FARADAY (WESTERN DIGITAL)	FE5400 CHIP SET: FE5000, FE5010 FE5020 FE5030	20 MHz			 •		 •	 •	 •		 •		 CMOS 132-PIN B/CMOS 132-PIN	$99 (4-CHIP SET) SAMPLES	HIGH-INTEGRATION 4-CHIP SET FOR IBM PS/2 MODEL 50 AND 60 CLONE MOTHERBOARDS. INCLUDES MICRO CHANNEL CONTROL. PS/2 EVALUATION BOARD WITH PHOENIX BIOS, $2500.
8086/88	FUJITSU	89391 89392 89393 89395	8 MHz			• • • •		• • • •	• • • •	• • •				CMOS 5V 100-LEAD FLAT PACK	$22.50 $21.20 $22.50 $19.70	HIGH-INTEGRATION CHIPS COMPATIBLE WITH IBM PC/XT. SAID TO NEED ONLY ADDRESS LATCHES AND DATA TRANSCEIVERS EXTERNALLY.
80286 80386	FUJITSU	89396	10 MHz			•		•	•					CMOS 5V 120-LEAD	$23.90 SAMPLES	HIGH-INTEGRATION CHIP FOR IBM PC/AT (80286 OR 80386 μP).
80286 (PC/AT)	ERSO	83745 83746 83747	8, 10 MHz	 •	 •	• • •		•	• • •	• •		• • •		CMOS 5V 68-LEAD PLCC	$60 KIT ($110 BOARD) SAMPLES	HIGH-INTEGRATION CHIP SET FOR BUILDING PC/AT CLONES. FROM TAIWAN FOUNDARY. ALSO 83748/9 FOR ADDRESS AND DATA.

— = NOT APPLICABLE
NA = NOT AVAILABLE
THE VOLUME OF AVAILABLE SUPPORT CHIPS PREVENTS INCLUSION OF ALL APPROPRIATE DEVICES IN THIS DIRECTORY. FOR MORE INFORMATION, REFER TO THE MANUFACTURER/PRODUCT LISTING AT THE BEGINNING OF THE DIRECTORY.

TABLE GROUP 3—PERIPHERAL-DEVICE CONTROLLER CHIPS

3A DISK CONTROLLERS

RELIEVE μP AND ITS OPERATING SYSTEM OF HARDWARE AND SOFTWARE OVERHEAD REQUIRED TO READ, WRITE, AND SEARCH FOR RECORDS IN PROPER DISK FORMAT. CHORES INCLUDE HEAD POSITIONING, CRC GENERATION, PROGRAM SECTOR SIZE, ETC. SEVERAL STANDARDS LIKE SCSI NOW APPLICABLE (SEE **TABLE 1A** FOR SCSI CHIPS).

μP BUS COMPATIBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: COMPATIBILITY	DRIVES HANDLED	FEATURES	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
8051 Z8 80188	SMC	95C00	20 MHz	SCSI ESDI SMD ST506 QIC-24 FLOPPY	—	12-BYTE FIFO 24-BIT DATA COUNTER BIDIRECTIONAL I/O PROGRAMMED DMA	CMOS 5V 68-LEAD PLCC QUAD FLAT PACK	$19	COMPATIBLE WITH SUPPLIER'S 95C02 "SUNDAE."
8051 Z8 80188	SMC	95C02	24 MHz	ESDI SMD ST506 QIC-24 FLOPPY	—	LOADABLE RAM CONTROLLER. 64k+ CACHE CONTROLLER. IBM COMPATIBLE ECC, REED SOLOMON ECC. READ-AFTER-WRITE. NRZ, RLL, 2, 7, AND GCR ENCODE/DECODE.	CMOS 5V 68-LEAD PLCC AND QUAD FLAT PACK	$24	"SUNDAE" CONTROLLER FOR DISK, TAPE, OR WORM. MODIFIABLE ASIC FASHION VIA SUPERCELLS. PROGRAMMABLE FOR IN-USE FLEXIBILITY. ARBITRATES CACHE ACCESS.
GENERAL	SILICON SYSTEMS (SSI)	32H567	15 mSEC	—	—	SERVO DEMODULATOR QUADRATURE SERVO PLL SYNCHRONIZED	BIPOLAR 24-PIN DIP 28-PIN PLCC	$13.88	CHIP SET FOR DISK DRIVE POSITIONING AND CONTROL.
		32H568				SERVO CONTROLLER TRACK AND SEEK, μP INTERFACE	CMOS 32-PIN DIP 44-PIN PLCC	$22.79	
		32H659				SERVO MOTOR DRIVE HEAD PARKING AND SPINDLE MOTOR BRAKING	BIPOLAR 20-PIN DIP, SMALL OUTLINE	$6.46	
GENERAL	SILICON SYSTEMS	32C452	20M BPS	—	—	DISK-DRIVE CONTROL AIC-010-COMPATIBLE PROGRAMMABLE	CMOS 40-PIN DIP 44-PIN PLCC	$20.25	HIGH-DENSITY HARD-DISK CONTROL COMPONENT.
GENERAL	SILICON SYSTEMS	32C453	20M BPS	—	—	DUAL-PORT BUFFER CONTROLLER, AIC-300 COMPATIBLE. NON-MUX ADDRESSING TO 16k	CMOS 40-PIN DIP 44-PIN PLCC	$11.45	HIGH-DENSITY HARD-DISK CONTROL COMPONENT.
GENERAL 8051 8085 68HC11	CIRRUS LOGIC	SH120	—	SCSI	1	64k BYTE BUFFER MEMORY MANAGER	CMOS 5V 44-PIN PLCC	$15	MAKES SRAMs INTO DUAL-PORT BUFFER, OPTIMIZED FOR USE WITH SUPPLIER'S SH-130 FOR SCSI INTELLIGENT CONTROLLERS.

Continued on pg 162

3A DISK CONTROLLERS *(continued)*

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: COMPAT-IBILITY	DRIVES HANDLED	FEATURES	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL 8051 8085 68HC11	CIRRUS LOGIC	SH130	20M BPS	ST506 ESDI SMD SA100	1	FLEXIBLE FORMATTER, 31 BYTES WRITABLE CONTROL STORE, PROGRAMMABLE 32-BIT ECC	CMOS 5V 44-PIN PLCC	$22	HARD-DISK FORMATTER. CAN BE COMBINED WITH SUPPLIER'S SH120 FOR SIMPLIFIED IMPLEMENTATION OF SCSI.
GENERAL 8051 8085	CIRRUS LOGIC	SH250	24M BPS	ST506	1	COMBINES FORMATTER, BUFFER MANAGER, AND SCSI BUS CONTROLLER. 56-BIT ECC WITH HARDWARE CORRECTION. 31 BYTES WRITABLE CONTROL STORE.	CMOS 5V 84-PIN PLCC	$38	HIGHLY INTEGRATED SCSI DISK CONTROLLER FOR HIGH-VOLUME EMBEDDED CONTROLLERS. PINOUT OPTIMIZED FOR BOARD LAYOUT EFFICIENCY. ON-CHIP 48-mA SCSI BUS DRIVERS.
GENERAL 8051 8085 68HC11	CIRRUS LOGIC	SH260	24M BPS	ST506 ESDI	2	COMBINES FORMATTER, BUFFER MANAGER, AND PC XT/AT BUS CONTROLLER. 56-BIT ECC WITH HARDWARE CORRECTION. 31 BYTES WRITABLE CONTROL STORE.	CMOS 84-PIN PLCC	$48	HIGHLY INTEGRATED PC XT/AT BUS DISK CONTROLLER FOR HIGH-VOLUME EMBEDDED USE. LOGIC FOR DAISY CHAINING 2 DRIVES. ON-CHIP 24-mA DRIVERS. SUPPORTS 1:1 INTERLEAVE.
GENERAL	NATIONAL	8472N 8474V	125k TO 1.25M BPS (PROGRAMMABLE)	FLOPPY DISKS: 3½ 5¼ 8 IN.	2 4	ANALOG DATA SEPARATOR, COMPATIBLE WITH 765A, 8-mA FDD BUFFERS, WRITE PRECOMPENSATION, MOTOR ON/OFF.	CMOS 5V 40-PIN DIP, 44-LEAD PLCC	$15	FDD CONTROLLER, CAN BE USED IN ALL GENERAL-PURPOSE APPLICATIONS. LOW-POWER MODE.
GENERAL	NATIONAL	8473V	250k, 300k, 500k, 1M BPS	FLOPPY DISKS: 3½ 5¼ 8 IN.	4	LOGIC FOR IBM PC, XT, AT OR PS/2. COMPATIBLE WITH 765A AND IBM BIOS. 40-mA FDD BUFFERS.	CMOS 5V 48-PIN DIP, 52-LEAD PLCC	$20	FDD CONTROLLER FEATURING DATA SEPARATOR WITH LARGE WINDOW MARGIN FOR REDUCED FDD ERROR AND LOW-POWER MODE FOR LAPTOPS.
GENERAL (8, 16, 32 BIT μP)	NATIONAL	8466A-12 -20 -25	12M, 20M, 25M BPS	ST506 SMD ESDI (FLOPPY, OPTICAL)	16	MULTIPLE SECTOR TRANSFER, PROGRAMMABLE FORMAT, AND ECC (48 BITS). 32-BIT FIFO WITH INTERLEAVABLE BURST AND DUAL 16-BIT DMA.	CMOS 5V 40-PIN DIP, 68-LEAD PLCC	$100 $125 $150	HARD- OR FLOPPY-DISK CONTROLLER, SAID TO BE SUITED TO ANY DRIVE OR BUS INTERFACE.
GENERAL	NEC	72068 72069	8 MHz 16 MHz	FLOPPY DISKS: IBM, ECMA FORMATS	4	765 COMPATIBLE. 24-mA DRIVERS, 8 BYTE REGISTERS FOR AT AND PS/2 ADDRESSING.	CMOS 5V 80-LEAD QUAD FLAT PACK 84-LEAD PLCC	$12 $14	SINGLE-CHIP FLOPPY-DISK CONTROLLER WITH ADDITIONAL LOGIC FOR IBM AT, PS/2 PLATFORMS. 68 HAS DIGITAL PLL; 69 HAS ANALOG PLL (1M BPS).

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3B SERIAL TAPE CONTROLLERS

DEMAND FOR STREAMING TAPES FOR HARD-DISK BACKUP HAS CAUSED A REAWAKENING OF INTEREST IN THIS CATEGORY. INTERPRET HIGH-LEVEL READ, WRITE, AND SEARCH COMMANDS ISSUED BY μP AND GENERATE DETAILED MOTION-CONTROL SIGNALS. ALSO CONVERT PARALLEL DATA FROM μP BUS TO SERIAL FORMAT, SOMETIMES PROVIDING ERROR DETECTION. SOME INTEREST IN HAVING STANDARD BUSES LIKE SASI, SCSI, ETC.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: COMPAT-IBILITY	DRIVES HANDLED	FEATURES	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
8051 Z8 80188	SMC	95C02	24 MHz	ESDI SMD ST506 QIC-24 FLOPPY	—	LOADABLE RAM CONTROLLER. 64k+ CACHE CONTROLLER. IBM-COMPATIBLE ECC, REED SOLOMON ECC. READ-AFTER-WRITE. NRZ, RLL, 2, 7, AND GCR ENCODE/DECODE.	CMOS 5V 68-LEAD PLCC AND QUAD FLAT PACK	$24	"SUNDAE" CONTROLLER FOR DISK, TAPE, OR WORM. MODIFIABLE ASIC FASHION VIA SUPERCELLS. PROGRAMMABLE FOR IN-USE FLEXIBILITY. ARBITRATES CACHE ACCESS.

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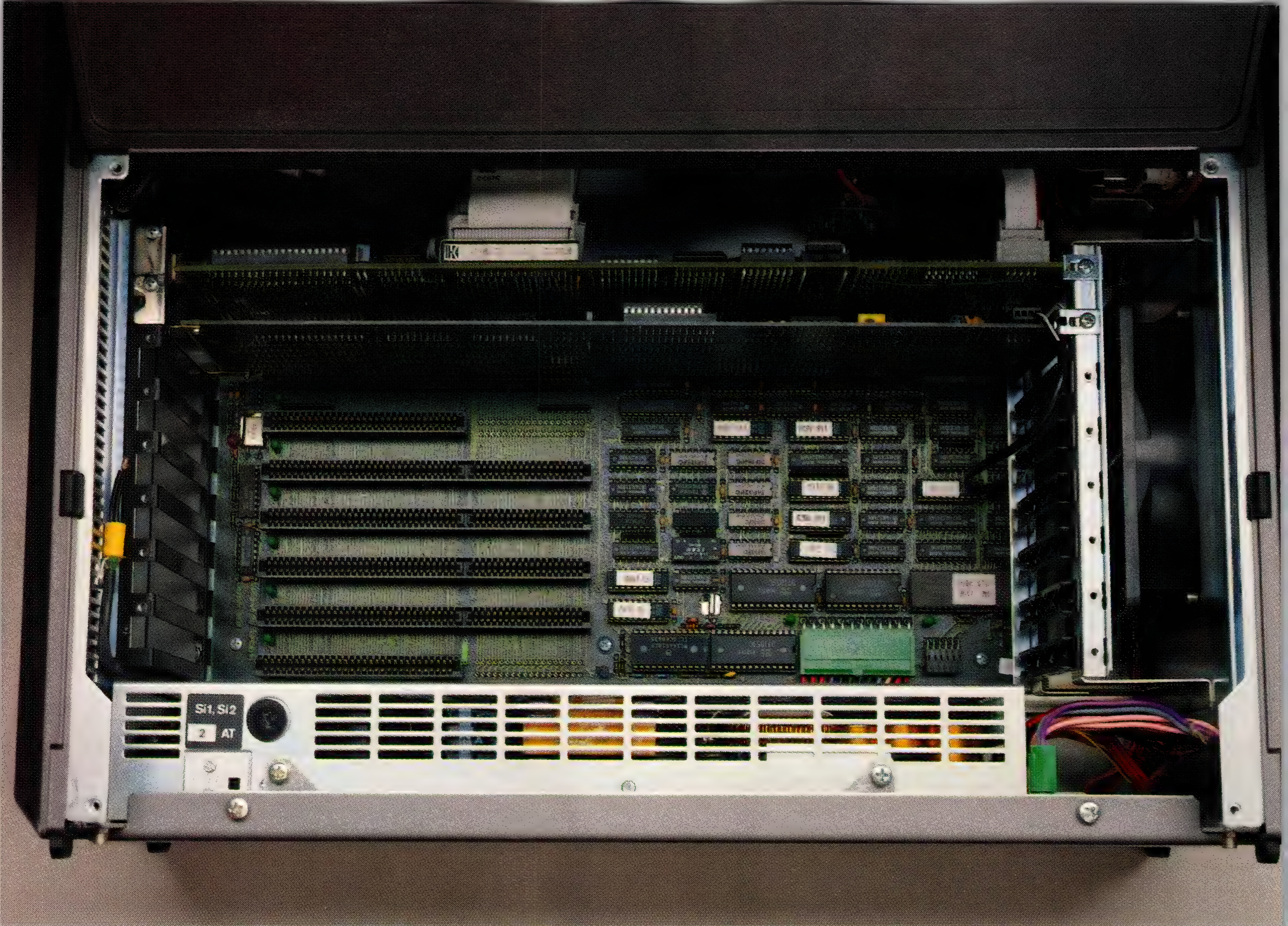
3C CRT (AND LASER-PRINTER) CONTROLLERS AND GRAPHICS GENERATORS

ACCEPT SETUP COMMANDS FROM μP THAT DEFINE DESIRED DISPLAY (USUALLY A RASTER TYPE) AND THEN IMPLEMENT AND MAINTAIN THE DISPLAY AUTOMATICALLY. FUNCTIONS OFTEN INCLUDE FORMATTING DATA FROM μP BUS FOR VIDEO PRESENTATION TO CRT, USING CHARACTER-GENERATING CHIP IF REQUIRED. TEXT AND GRAPHIC MODES, AS WITH DISKS (**TABLE 3A**) STANDARDS ARE EMERGING. RECENT TREND IS POWERFUL GRAPHIC ENGINES THAT CAN, FOR EXAMPLE, CREATE 3D PICTURES OF OBJECTS WITH PERSPECTIVE AND SHADING, AND ROTATE SAME. LASER PRINTER CONTROLLERS MAY BE INCLUDED AS THEY HAVE SIMILAR 'RASTER' SCAN.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: PROGRAMMABLE DISPLAY FORMAT	PROGRAMMABLE MONITOR FORMAT	GRAPHIC CAPABILITY	CURSOR/ LIGHT PEN	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL	SMC	97C07	4.5 MHz (CHAR) 42 MHz (DOT)	YES	YES		YES	CMOS 5V 84-LEAD PLCC	$15	SINGLE-CHIP PROGRAMMABLE CRT CONTROLLER. FOR LOW-COST DEC 220, 320 COMPATIBLE ALPHANUMERIC TERMINALS.
GENERAL	SMC	97C11	7.5 MHz (CHAR)	YES	YES		YES	CMOS 5V 68-LEAD PLCC	$35	PROGRAMMABLE CRT CONTROLLER THAT SUPPORTS HARDWARE-BASED WINDOWING.



We Suggest You Approach Your Logic Analyzer Decision Backwards.

Up front, the PLA 286 gives you more of what you need to solve even the toughest timing problems. Much deeper memory, for example, than you'll find anywhere else: Up to 4K per channel for state analysis; up to 8K for timing. And from 48 up to 112 channels. So you get a much bigger window into problem areas.

But what you see when you look behind the machine may impress you even more. Because in addition to being a powerful logic analyzer, it's also a powerful 10-MHz, 0-wait-state, AT-compatible computer.

There they are. Count 'em.

Six standard slots, waiting to turn the PLA 286 into anything else you want it to be. Now, or later. Pattern generator. Oscilloscope. SCSI tester. Frequency counter. Ethernet node. Whatever.

So when you look at it backwards, the PLA 286 is a very forward-thinking machine, indeed. Fold up the keyboard, grab the handle, and it moves from heavy-duty, complex R&D lab applications, to complete, multi-function field analysis. All the power, depth, range, and flexibility you need for the most demanding software and hardware analysis, in one, neat box.

The PLA 286 is one decision you can back into, and feel great about. Give us a call. (800) 227-8834.

KONTRON ELECTRONICS

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3C CRT (AND LASER-PRINTER) CONTROLLERS AND GRAPHICS GENERATORS *(continued)*

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: PROGRAM-MABLE DISPLAY FORMAT	PROGRAM-MABLE MONITOR FORMAT	GRAPHIC CAPABILITY	CURSOR/ LIGHT PEN	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL	CIRRUS LOGIC	GD 510/520	40 MHz	YES, FROM 320×200 TO 800×600	YES, ALL IBM STANDARDS	YES, VGA, EGA, CDA, HGC	YES, HARDWARE GRAPHICS CURSOR	CMOS 5V 84-PIN PLCC	$38 (SET)	2-CHIP SET. 100% REGISTER COMPATIBLE WITH VGA, EGA, CGA, AND HERCULES WITH AUTOMATIC MODE SWITCHING. SUPPORTS ANALOG AND DIGITAL MONITORS.
GENERAL	NATIONAL	DP 8500	20 MHz	YES, 16k×16k PIXEL	YES	YES, BITBLT LINE DRAW POLY FILL CHARACTER	NO	CMOS 5V 68-PIN PLCC	$125	RASTER GRAPHIC PROCESSOR (RGP), FULLY PROGRAMMABLE GRAPHIC μP. COLOR OR B/W. WORKS WITH SRAM, DRAM, OR VRAM. PART OF AGCS CHIP SET.
GENERAL	NATIONAL	DP 8510 DP 8511	20 MHz	—	—	BITBLT	—	CMOS 5V 44-PIN PLCC	$8 $16	SUPPORTS ALL 16 BITBLT FUNCTIONS, COMPATIBLE WITH DRAMs, SRAMs, AND VRAMs. HIGH-SPEED BARREL SHIFTS FOR NONWORD-ALIGNED BLTs. 16-WORD FIFO.
GENERAL	NATIONAL	DP 8512 DP 8513	225 MHz	—	—	—	—	BIPOLAR 44-PIN PLCC	$45	ON-CHIP CRYSTAL OSCILLATOR AND PLL GENERATE SYNCHRONIZED SYSTEM CLOCKS. EXTERNAL GEN-LOCK CAPABILITY WITH SEPARATE PLL TO OVERLAY GRAPHICS OR TEXT ONTO INCOMING VIDEO.
GENERAL	NATIONAL	DP 8514	225 MHz	—	—	—	—	BIPOLAR 20-PIN	$3	MULTIBOARD CLOCK SYSTEM WITH ON-CHIP CRYSTAL OSCILLATOR AND RESYNCHRONIZER.
GENERAL	NATIONAL	DP 8515 DP 8516	225 MHz 350 MHz	—	—	—	—	BIPOLAR-CMOS 44-PIN PLCC	$16	4-WORD FIFO, 16-BIT REGISTER OR 2 8-BIT REGISTERS. SINGLE +5V SUPPLY OR ± ECL SUPPLIES. 8515 HAS 10k ECL OUT; 8516 HAS 100k ECL OUT.
GENERAL	WEITEK	XL-8000 (TWO CHIPS)	10 MHz	—	—	DRAWS 60k VECTORS/ SEC. FILLS 9.6 PIXEL/ SEC.	—	CMOS 144-PIN PACKAGE	$590	FAMILY OF 32-BIT μPs OPTIMIZED AS GRAPHICS GENERATORS. THEY PERFORM 2D DRAW AND FILL OPERATIONS AND ARE SUPPORTED BY C AND FORTRAN COMPILERS. 8000 IS 32-BIT μP FOR 2D GRAPHICS; 8032 IS FLOATING POINT μP FOR 3D GRAPHICS TRANSFORMS; 8064 IS 64-BIT μP FOR 3D OPERATIONS SUCH AS RAY TRACING.
		XL-8032	10 MHz	—	—	SAME AS 8000 PLUS TRANSFORMS 200k 3D VECTORS/ SEC	—	CMOS 144-PIN PGA	$790	
		XL-8064 (THREE CHIPS)	10 MHz	—	—	SAME AS 8032	—	CMOS 144-PIN PGA	$590	
GENERAL	NEC	72120	8 MHz	YES 4k×4k 32M BYTE	YES	YES	YES	CMOS 5V 132-LEAD PGA 84-LEAD PLCC 94-LEAD QUAD FLAT PACK	$50	FIRMWARE-ENCODED INSTRUCTION SET FOR HIGH-SPEED DRAWING, PAINT, FILLS, ARCS, ELLIPSES, BIT BLT, ENLARGE, ROTATE, ETC. VRAM CONTROLLER, DIRECT ACCESS BY HOST.

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3D KEYBOARD AND NON-CRT DISPLAY INTERFACES

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	DISPLAY BIT PATTERNS	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL	SILICONIX	9551 9552	4 MHz	AC EL MATRIX ROW DRIVERS, CHANNELS	D/CMOS 44-LEAD PLCC	$4.91	SERIAL INPUT, PARALLEL OUTPUT (SEQUENTIAL). 9552 PINOUT IS REVERSE OF 9551.
GENERAL	SILICONIX	9553 9554 9555 9556	10 MHz	AC EL MATRIX COLUMN DRIVERS, 32 CHANNELS	D/CMOS 44-LEAD PLCC	$4.91, $5.66	SERIAL INPUT WITH LATCH, PARALLEL OUTPUT. 9553, 9555 PINOUTS ARE REVERSE OF 9554, 9556. 9553, 9554 HANDLE 60V, 9555, 9556 HANDLE 90V.
GENERAL	SILICONIX	9559	10 MHz	DC EL MATRIX CONSTANT-CURRENT COLUMN DRIVER	D/CMOS 44-LEAD PLCC	NA NA	SERIAL INPUT WITH LATCH, PARALLEL OUTPUT. PROGRAMMABLE RIGHT OR LEFT SHIFT.
GENERAL	SMC	9600-STD	—	—	NMOS 40-PIN DIP 44-LEAD PLCC	$8.80	ASCII VERSIONS OF 9600 AND 9602 KEYBOARD ENCODERS. NMOS SAID TO BE SUPERIOR TO CMOS FOR ESD RESISTANCE, 3000 TO 4000V.
		9602-012	—	—	28-PIN DIP 28-LEAD PLCC	$7.30	
GENERAL	MICROCHIP TECHNOLOGY	AY04381	1.5 MHz	32 LCD SEGMENTS	CMOS 3 TO 10V	$3.38	SERIAL INPUT.
GENERAL	CYBERNETIC MICROSYSTEMS	CY325	—	8 ROWS×40 CHARACTERS, 64×240-PIXEL GRAPHICS. UP TO 256 BUILT-IN WINDOWS WITH FIRMWARE PROVIDING EASY-TO-USE HIGH-LEVEL COMMANDS.	CMOS 5V 40-PIN DIP	$50	LCD WINDOWS CONTROLLER. (80C51 μC WITH PROPRIETARY CODE). 8 SOFT KEYS FOR MENU RESPONSE, ETC.

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3E POWER DRIVERS AND CONTROLLERS

MANY OF THESE DEVICES CAN DRIVE THE INDUCTIVE LOADS OF ELECTROMECHANICAL MACHINERY. NEW EMPHASIS IS TO MAKE THEM "SMART," INCORPORATING SELF-CONTROL AND ABILITY TO FEED BACK INFORMATION TO HOST μP. NEW SEMICONDUCTOR TECHNOLOGIES SUCH AS BiMOS, BiCMOS, ETC, ARE BEING EXPLORED.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	KEY SPECIFICATIONS: OUTPUT SPEED	KEY SPECIFICATIONS: OTHER FEATURES	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL	SPRAGUE	UCN5804B	—	1.25A, 35V OUT	BiMOS 16-PIN DIP	$2.65	UNIPOLAR STEPPER MOTOR TRANSLATOR/ DRIVER WITH TRANSIENT SUPPRESSION.
GENERAL	SPRAGUE	UCN5871B UCN5871EB	—	1A, 45V OUT	BiMOS 22-PIN DIP, 44-LEAD PLCC	$4.36 $4.56	TRANSLATOR/DRIVERS FOR BIPOLAR STEPPER MOTORS.
GENERAL	SPRAGUE	UDN2987A	—	350 mA, 35V OUT	BIPOLAR 20-PIN DIP	$1.69	8-CHANNEL SOURCE DRIVER WITH OVER-CURRENT PROTECTION AND FAULT FLAG.
GENERAL	SPRAGUE	UDN2543B	—	700 mA, 25V OUT	BIPOLAR 16-PIN DIP	$2.47	4-CHANNEL DRIVER, FULLY PROTECTED FOR INCANDESCENT AND INDUCTIVE LOADS.
GENERAL	SPRAGUE	UDN2931B UDN2931W	—	±2A, 15V OUT	BIPOLAR 22-PIN DIP 12-PIN SIP	$3.76 $4.03	3-PHASE BRUSHLESS MOTOR POWER DRIVERS, SATURATING OUTPUTS WITH TRANSIENT PROTECTION.
GENERAL	SPRAGUE	UCN5801A UCN5801EP	—	350 mA, 50V OUT	BiMOS 22-PIN DIP 28-LEAD PLCC	$1.81 $2.07	8-BIT LATCHED DRIVERS WITH OUTPUT SUPPRESSION. 5-MHz BUS SPEED.
GENERAL	IXYS	IXDP610	0 TO 300-kHz SWITCHING FREQUENCY	BUS-COMPATIBLE DIGITAL PWM CONTROLLER. 7- OR 8-BIT RESOLUTION. PROGRAMMABLE DEAD TIME AND PROTECTION AGAINST HARDWARE/ SOFTWARE FAILURES.	CMOS 18-PIN SLIM DIP	$8.42	ACCEPTS COMMANDS FROM μP AND GENERATES TWO COMPLEMENTARY OUTPUTS FOR CONTROL OF POWER BRIDGE. 20-mA TTL OUT.
GENERAL	SILICONIX	D-469	100-nSEC PROP DELAY	500-mA SOURCE AND SINK OUTPUTS (2% DUTY CYCLE). TTL LOGIC INPUTS. H-BRIDGE DRIVER.	CMOS 5, 14V 14-PIN CIP	$2.92	QUAD "MOSPOWER" DRIVER, INVERT AND NONINVERT INPUTS. LOW ON-RESISTANCE OUTPUTS.

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TABLE 4—μPs AND μP-LIKE CHIPS

THE ULTIMATE IN FLEXIBILITY, THESE GENERAL-PURPOSE μCs AND μPs ARE INCLUDED HERE BECAUSE THEY ARE SO WIDELY USED IN LIEU OF THE DEDICATED CONTROLLER CHIPS LISTED IN OTHER TABLES OF DIRECTORY (FOR EXAMPLE, THE 8051 μC—LIKE ITS FORERUNNER, THE 8048—IS WIDELY USED IN LIEU OF THE KEYBOARD CONTROLLERS OF TABLE 3D). THE CURRENT TREND IS THE USE OF MORE POWERFUL 16-BIT AND EVEN 32-BIT μP/μCs FOR SOPHISTICATED PERIPHERALS LIKE LASER PRINTERS.

μP BUS COMPAT-IBILITY	SUPPLIER	MODEL	SPEED	KEY SPECIFICATIONS: ROM	KEY SPECIFICATIONS: RAM	KEY SPECIFICATIONS: PORT (BITS)	KEY SPECIFICATIONS: TIMER (BITS)	TECHNOLOGY/ PACKAGE	PRICE (100)	COMMENTS
GENERAL 8 BITS	INTEL	UPI-452 87C452	12, 16 MHz	8k×(8) EPROM	256×(8)	40	2×16	CMOS 5V 68-PIN PGA PLCC	$70 NOW	80C51 μC PLUS 128-BYTE 2-CHANNEL BIDIRECTIONAL FIFO BUFFER AND 2-CHANNEL DMA.
GENERAL 8 BITS	AMD	80C321 80C521 87C521	12, 16 MHz	0 (ROMLESS) 8k×(8) ROM EPROM	256×(8)	4×(8)	2×(16) (WATCH-DOG)	CMOS 5V 40-PIN 44-PIN PLCC	$8.85 NOW $8.50 (1k QTY) NA	ENHANCEMENT OF INTEL 8051 μC. FEATURES FAIL-SAFE WATCHDOG TIMER AND EXTRA DATA POINTER.
GENERAL 8 BIT	NATIONAL SIERRA	COP800	1-μSEC INSTR CYCLE	1k TO 4k (ALSO EEPROM)	64 TO 192 (ALSO EEPROM)	16 TO 36	16 (ALSO WATCHDOG AND IDLE)	CMOS 2.5 TO 6.0V 20- TO 40-PIN DIP AND SURFACE-MOUNT	$0.99 TO $13 IN VOLUME; AVAILABLE NOW	SAID TO BE 8-BIT VERSION OF ORIGINAL 4-BIT COP BUT DIFFERENT ARCHITECTURAL DETAILS AND INSTRUCTION SET.
6800 8 BIT	MOTOROLA RCA	68HC805C4 68HC805C8	2.0 MHz	4k×(8) EEPROM 8k×(8) EEPROM	176×(8)	32 4×(8)	1×(16)	CMOS 5V 40-PIN 44-PIN PLCC	$49.50 NOW NA	EEPROM VERSIONS OF 68HC805C4 AND 68HC05C8.
GENERAL 8 BITS	TI	TMS 370XX0	20 MHz	4k TO 16k	128 256 512	22 55 (INCLUDING UART)	2×16 24 WATCHDOG	CMOS 5V 28-PIN DIP, PLCC 68-LEAD PLCC	$3 $7 $4.50 TO $10 SAMPLES	HIGH-END 8-BIT μC. OPTIONAL 8-BIT, 8-CHANNEL A/D. ADDITIONAL LARGE CHIP WITH EEPROM PROGRAM MEMORY IS DEVELOPMENT TOOL.
GENERAL 16 BIT	NATIONAL	16040	17, 20 MHz	2k×(16)	128×(16)	52	8×(16)	CMOS 5V 68-PIN PCC LCC, PGA	$10 NOW	16-BIT CONTROLLER WITH UART AND MICRO-WIRE SERIAL PORTS.
GENERAL 32 BIT	VLSI TECH	86C010 ARM	8 MHz (4 MIPS)		25×(32) REGISTER FILE	—	—	CMOS 5V 88-PIN LCC	$30 (IN VOL) NOW	32 BIT μP. EXAMPLE OF NEW RISC ARCHITECTURE SAID TO MAKE FOR SIIMPLICITY AND LOW COST WITH 32-BIT PERFORMANCE. WILL PROBABLY BE USED FOR SUPPORT SUBSYSTEMS.
GENERAL 32 BIT	INTEL	80960 KA, 80960 KB, 80960 MC	20 MHz (7.5 VAX MIPS, 15k DHRY)	—	32×32 REGISTERS, 512 CACHE	—	—	CMOS 5V 132-LEAD PGA	$390 $174 $2400 MILITARY KA. NOW; KB, 4 QTR	RISC-TYPE μP WITH OPTION OF ON-CHIP FLOATING PT. ITS PERFORMANCE SAID NEEDED FOR SUPPORT FUNCTIONS LIKE LASER-PRINTER CONTROL.

— = NOT APPLICABLE
NA = NOT AVAILABLE
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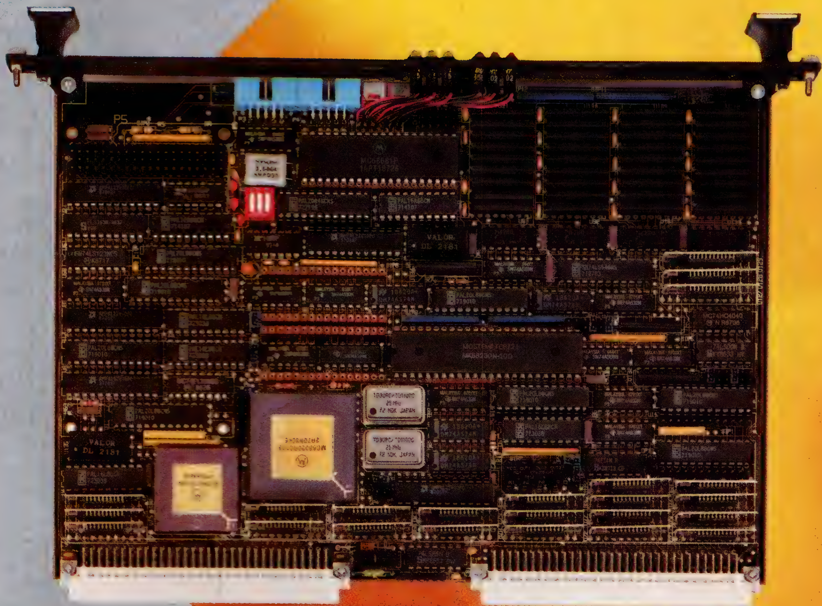

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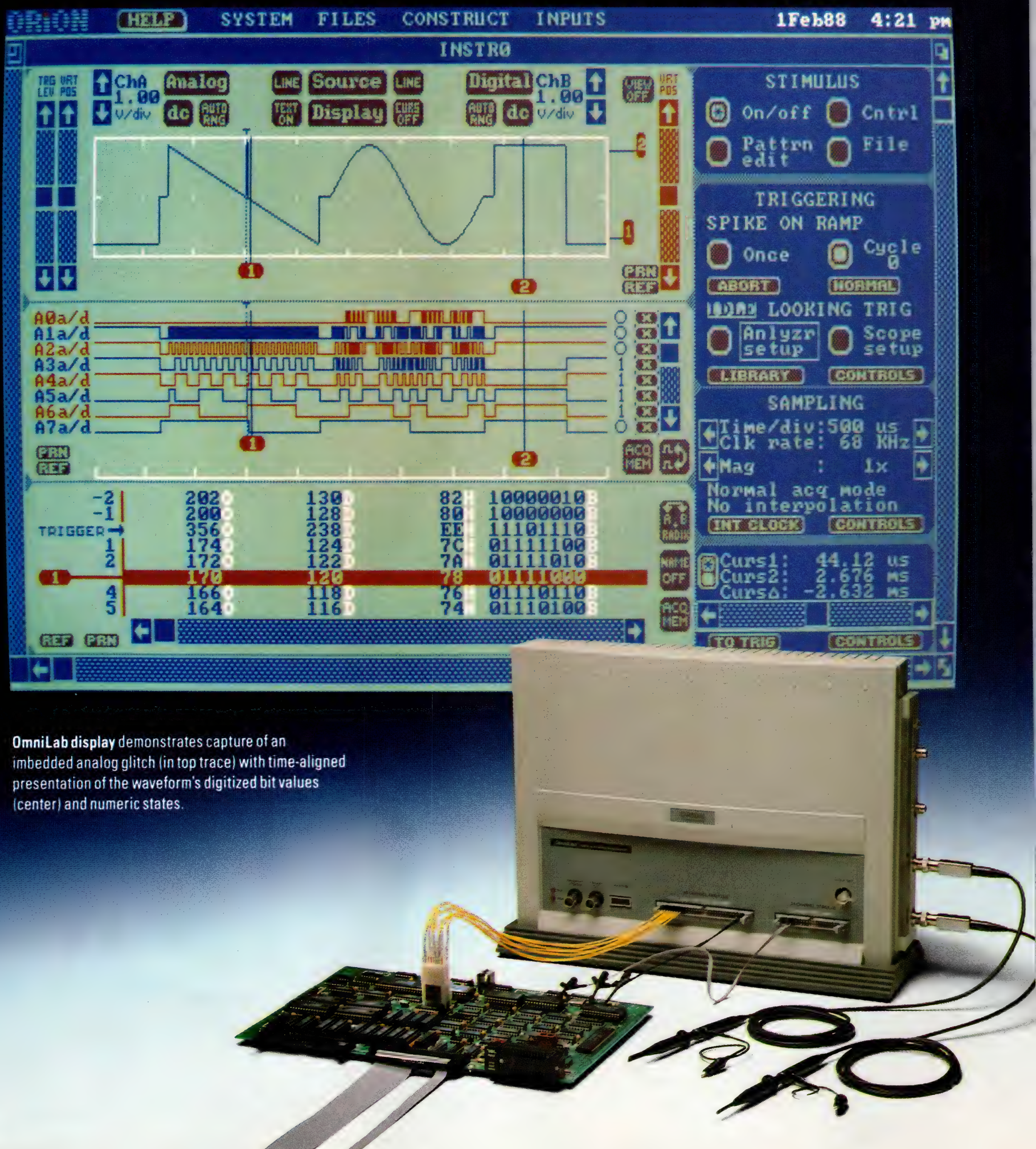

OmniLab display demonstrates capture of an imbedded analog glitch (in top trace) with time-aligned presentation of the waveform's digitized bit values (center) and numeric states.

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Combine a 100 MHz digital oscilloscope with a time-aligned, 200 MS/s 48-channel logic analyzer. Next add synchronized analog **and** digital stimulus generators. Then a remarkable new triggering system. What you have is the 9240 — a whole **new class** of instrumentation. Expressly designed to speed challenging analog and digital analysis. And get you from concept to product faster.

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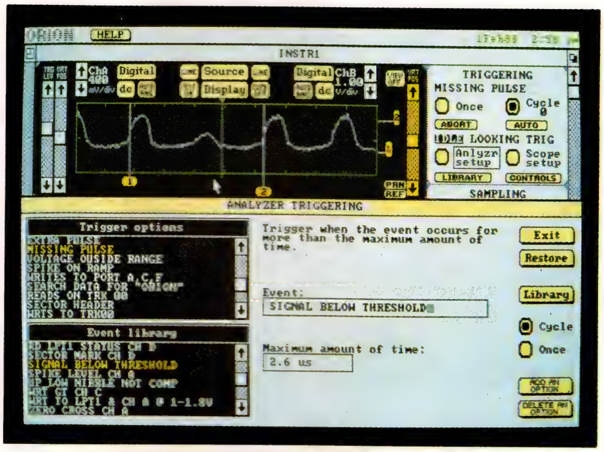
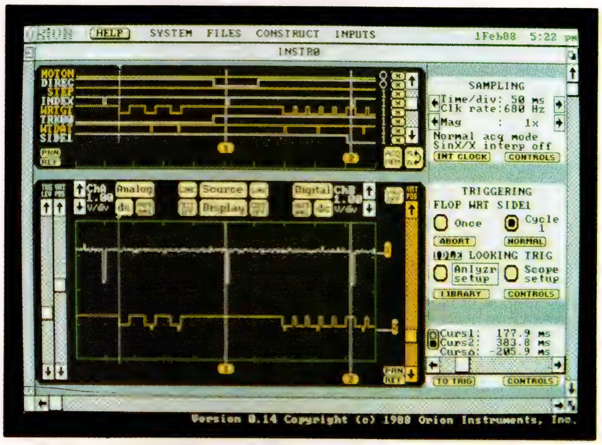


SELECT triggering on a rare event. Using Trigger Options and Event Library from the popup panel (at bottom), a trigger is selected to capture a dropout occurring when a disk drive index signal is below threshold for too long.



Logic timing analysis (top) of entire sequence for writing data to a floppy disk. Scope simultaneously displays detailed amplitude and multichannel timing information (bottom).

The 9240 is like having a complete benchtop of instruments integrated with your PC/AT or compatible. Which you can easily customize for digital development, analog development, or a combination of both.

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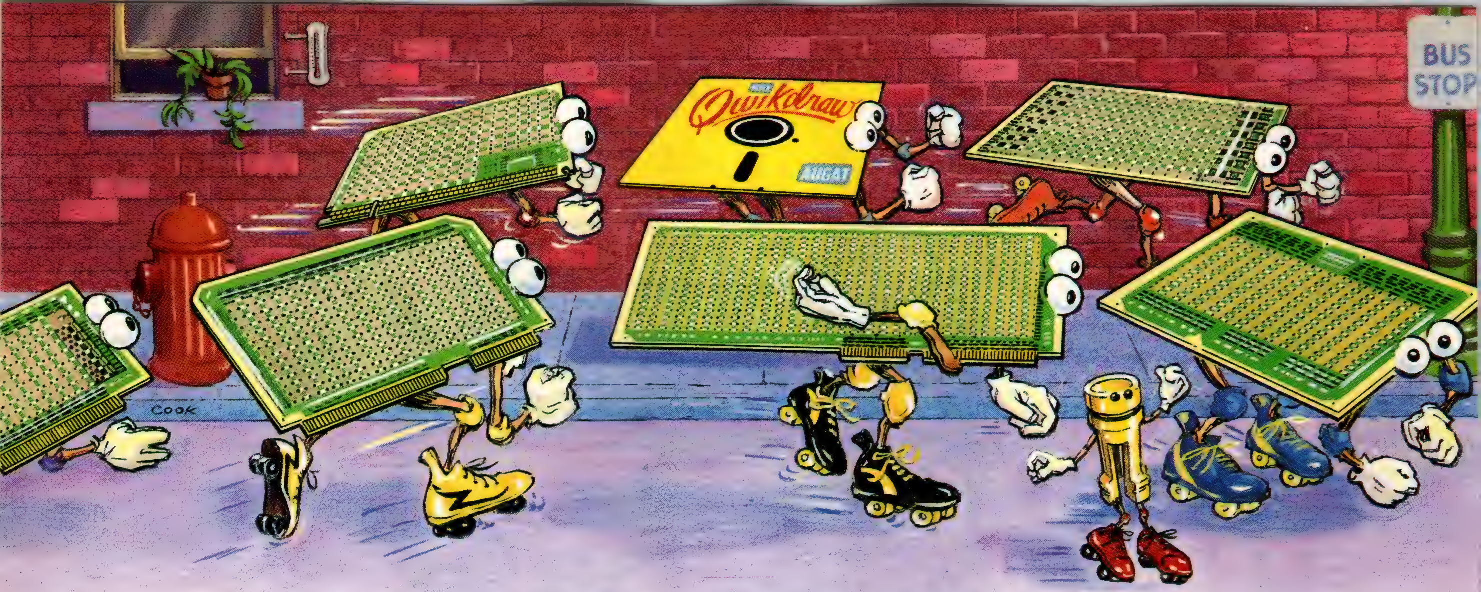

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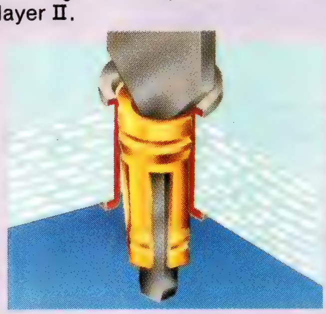

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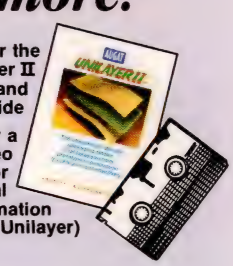

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Asynchronous state machines challenge digital designers

Part 1 of this 2-part series provided a brief refresher of the basic theory of state machines and gave two detailed examples of synchronous state-machine design with common PLDs. This article, part 2, continues with an example of a more difficult, asynchronous state machine. Part 2 also gives some background information on state-machine software packages and details a PLD whose architecture suits large state machines.

Stan Kopec, *Altera Corp*

Implementing state-machine designs in programmable-logic devices (PLDs) can solve some irksome control-logic design problems. If you elect to perform asynchronous state-machine design, however, be advised that it's more difficult than its synchronous counterpart. You should embark on an asynchronous state-machine design only when your application gives you no other choice.

Asynchronous state machines, by definition, will respond to any allowable input. Thus, they're susceptible to interference, noise, and glitches. Further, they require you to pay close attention to state assignment. Although careful state assignment is helpful but not critical in synchronous state-machine design, in asynchronous state machines it's crucial.

What's more, asynchronous designs are very sensitive to mismatched delays, races, and hazards. A race is a series of successive states that occurs during a state transition. A hazard occurs whenever more than one state variable changes at a time, resulting in unwanted transient states or potential decoding-logic glitches.

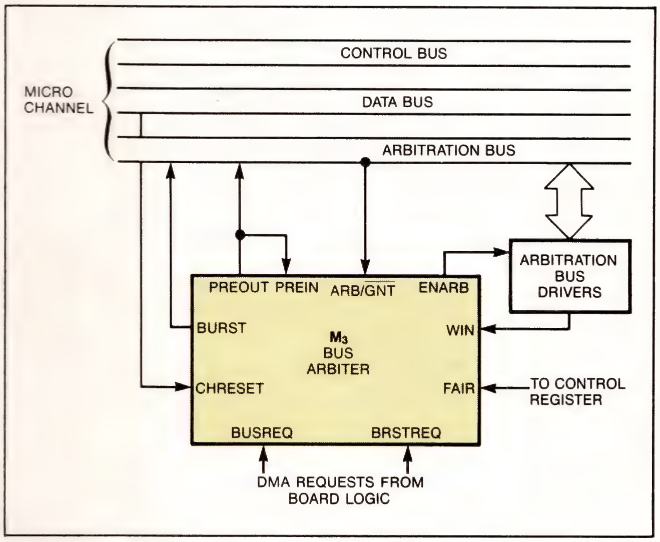

Fig 1—This bus arbiter *for the IBM PS/2 Micro Channel bus accepts DMA requests from external devices and then strives to gain control of the bus.*

The problem of asynchronous state-machine design is evident in **Fig 1**, which shows a bus arbiter for the IBM Micro Channel (the bus for the company's PS/2 computers). The arbiter, M_3, has eight states. **Fig 2a** shows the state diagram for the bus arbiter. The inputs are ARB/$\overline{GNT}$, PREIN, WIN, CHRESET, FAIR,

If you're implementing an asynchronous state machine in which the input-to-output delays are critical, you may want to put the intermediate states to work.

BRSTREQ, and BUSREQ; the outputs are PREOUT, BUSGNT, BURST and ENARB.

The arbiter operates as follows. Peripheral logic asserts the BUSREQ (single-cycle) or BRSTREQ (block-transfer) lines to request use of the Micro Channel. The arbiter state machine (M_3) responds by asserting PREOUT to the Micro Channel. In response, the PS/2's μP asserts ARB/$\overline{\text{GNT}}$, indicating that arbitration has begun. M_3 asserts ENARB to place its arbitration priority on the bus. If the bus value matches its priority when ARB goes low, the arbiter has won the bus, and it proceeds to transfer data after asserting BUSGNT. If the priorities do not match, the arbiter has lost and must wait for another arbitration cycle. During block transfers, the arbiter asserts BURST.

Because the state variables in asynchronous machines are sensitive to glitches, changing only one state variable at a time proves to be a good rule of thumb. When you look at M_3, you might assume that it requires only three state variables because it has eight states. In fact, M_3 requires six state variables to satisfy all the state adjacencies. You determine adjacencies by listing each state with the states connected to it by arrows in the state diagram. To make adjacent states differ by only one state variable, you may need to insert intermediate states **(Fig 2b)**.

In an asynchronous-machine design, you should decode invalid state-variable combinations to make the design more reliable. If the logic decodes an invalid state, it should reset the machine to an IDLE condition or an ERROR state. Thus, even if the machine misbehaves, at least it can't run amok.

Fig 3 (pg 184) shows the transition equations for M_3. M_3 is a Moore design. Its p-term requirements range from two to 14. If you used PLDs having eight p-term

Text continued on pg 184

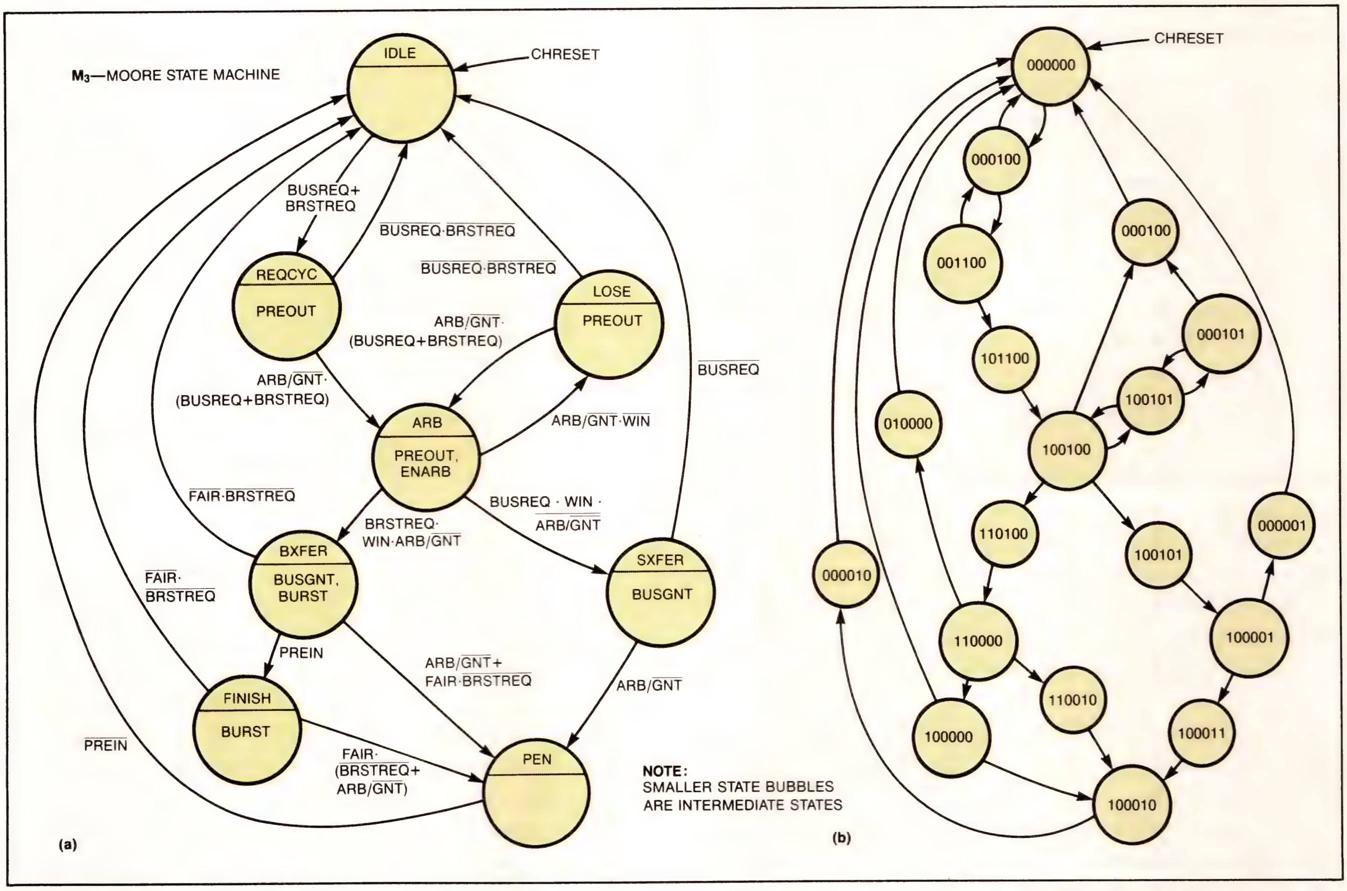

***Fig 2—The state-transition-diagram** in **a** is the formal definition of the bus-arbitration handshake for the IBM Micro Channel bus. The diagram in **b** has an extra intermediate state so that the M_3 state machine will operate without glitches. Note that M_3 requires six state variables, instead of only three, to specify the eight required states. The extra variables are needed to satisfy the requirement that each state transition change only one state variable.*

State-machine software speeds design

State machine and general-purpose PLD-design software can automate many of the rote tasks associated with state-machine design. **Fig A** shows the major blocks of such a package. Because some of these software packages minimize logic functions—for example, by selecting deMorgan's inversion where appropriate—they can save you considerable time and effort. Some state-machine packages will also try different flip-flop types in a quest for the minimal implementation (your target PLD must have these flip-flop types, of course).

Some of these software packages also allow high-level functional descriptions. For example, high-level syntax for state machines means that you can enter statements for transition specifications rather than transition equations. By automatically generating the transition equations from the high-level description, the software packages save you much error-prone rote work as you try out different state assignments.

The software tools can further aid in your design effort by automatically reducing these initial equations to a minimal form. JEDEC-file assembly from these minimal equations is a straightforward translation.

These packages also provide a simple functional simulation—or, less frequently, a timing simulation—from the JEDEC-file description of your state machine. You can typically compile a state-machine design and simulate it on your PC in minutes with any of this software. This relatively rapid iteration cycle is of particular value when you formulate your machine design, because complex control flows are prone to designer error. Seeing your machine's operation in an interactive simulation environment allows you to work the bugs out quickly before you go to the lab to make a breadboard.

Existing PLD-design tools don't handle tasks such as state-variable assignment for you. Neither do they detect or report races and hazards (asynchronous state-machine designers, watch out!). Mealy-to-Moore conversion is also left to you. These areas are where the art of state-machine design begins.

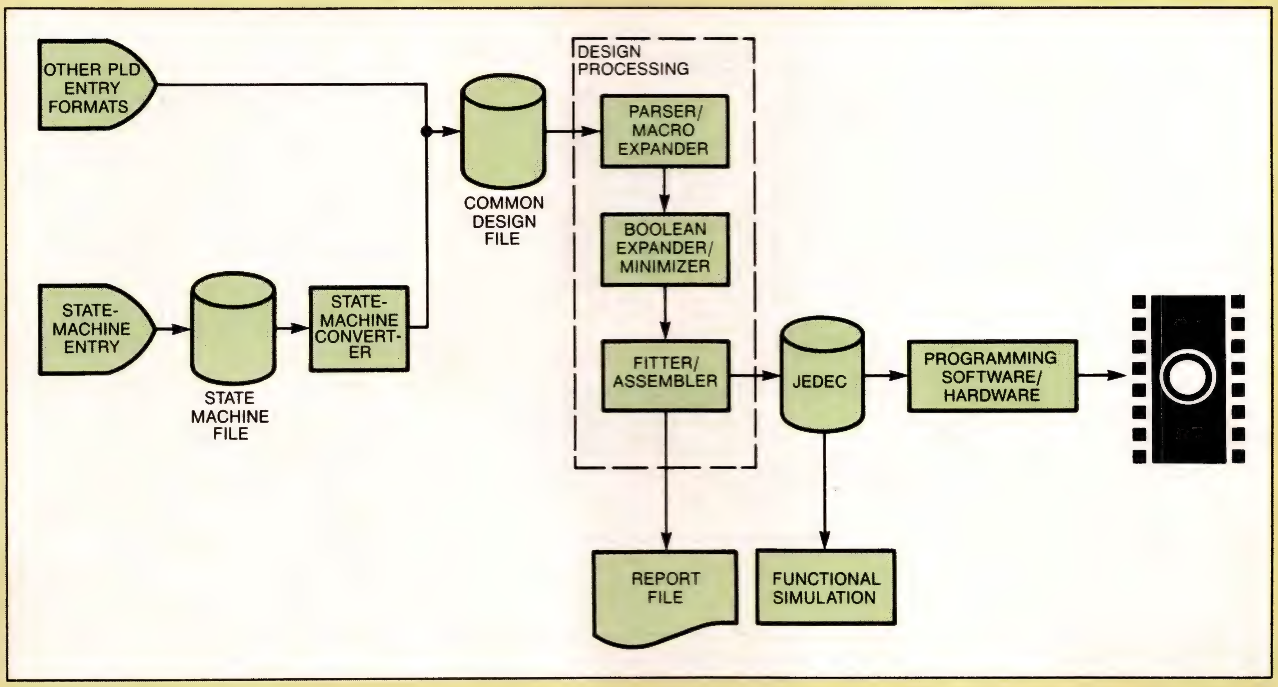

***Fig A—State-machine and general-purpose PLD-design software** can automate many of the rote tasks associated with state-machine design.*

New PLD architecture suits large state machines

The EPS448 SAM (stand-alone microsequencer) is a 28-pin, CMOS EPROM-based chip **(Fig A)**. It has a 768-p-term programmable-logic block for selecting one of four state-machine branches per state. It also includes 16k bits of microcode/state EPROM, an 8-bit loop counter, and a 15-level stack.

Functionally, you can consider the device to be a microcoded, instruction-based engine under the direction of a master programmable-logic block that determines branches.

The SAM's architecture implements a synchronous Moore state machine. A SAM can implement state machines with as many as 448 states. The device's 36-bit×448-word microprogram/state memory is organized into two sections: One section is one word wide for straight-line, unconditional sequences, and one section is four words wide for branching sequences.

Each microcode word has fields for the state of the device's outputs, a 3-state enable bit, an op code, and arguments for the op code. The arguments for the op code are the location in the microprogram memory of the next state to be jumped to, and, optionally, constants.

The branch-logic block combines the device's eight inputs and its present state (one of two 8-bit fields in the currently addressed word in the microprogram/state memory) to select one of four next states from among those in a branching-sequence memory location. Further, the SAM is unlike conventional PLDs in that its hold-state transitions consume no p-terms.

True to its microcoded architecture, the SAM can also perform functions more akin to those of a µP than to those of a classical state machine. For example, it can nest subroutines and execute timing loops. With the 8-bit, 256-state loop counter, in combination with the stack, you can generate arbitrarily long output-signal durations.

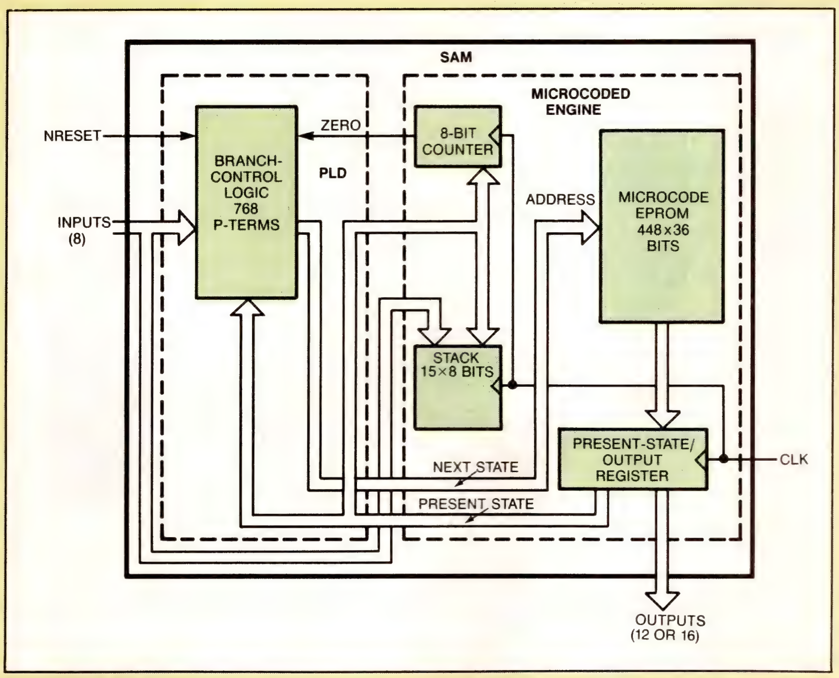

***Fig A—The EPS448 SAM (stand-alone microsequencer)** has a 768 p-term programmable-logic block for selecting one of four state-machine branches per state. Operating as a bit-slice processor does, the SAM also includes 16k bits of microcode/state EPROM, an 8-bit loop counter, and a 15-level stack.*

The SAM has a primitive instruction set with which you can invoke the counter and stack at required points in the state-machine flow. The instructions include call, return, push counter, load counter, decrement, and test counter. You can use these instruction-based operations in conjunction with the programmable-branch logic.

The counter in the SAM has several potential uses in applications such as the synchronous DMA controller (M_1) and the synchronous bus controller (M_2) detailed in part 1 of this series **(Ref 1)**. A bus-timeout function could force the termination of a bus cycle when READY does not occur within a specified time. If block data transfers involve a fixed-length (nonprogrammable) block of data, the counter could replace the external byte counter. To limit bus hogging, M_1 might transfer 16-byte subblocks, release the bus, and then request it again after some interval.

The stack on SAM could be used similarly to enhance M_1's and M_2's functioning. In a single-SAM implementation, M_2 could be a submachine (slave machine) called by M_1 to execute bus cycles. In this case, the stack would store the present state of the calling state machine, M_1. When it finished its bus cycle, M_2 would execute a return in order to restore M_1 to control of the SAM.

You can also use the stack to create extended timing loops when modulo 256 is too short. By nesting loops and using the counter, you can construct loops as long as 256^{15} iterations. In addition to subroutine nesting and timer loops, the stack can also store data. A sequencer supporting two or more independent DMA channels could use the stack for the temporary storage

and swapping of channel parameters, for example.

You can use multiple SAMs in parallel to increase the output-line count or to implement multichip controllers. Like memory chips, the architecture lends itself to modular expansion in both output width and microprogram depth.

Given the complexity of its architecture and the size of the design problems it addresses, the SAM requires high-level design software. The vendor's SAM+ software package can automatically compile your machine description from a text file. You can use high-level IF statements for state-machine transitions in conjunction with assembly-level SAM instructions that use counter and stack. You specify state outputs as vectors without worrying about logic or p-terms. **Fig B** shows a SAM specification for M_1.

Reference

1. Kopec, Stan, "State machines solve control-sequence problems," *EDN*, May 26, 1988, pg 177.


```
             SAM M1 DESIGN
PART:        EPS448
INPUTS:      BC0,STARTX,GRANT,DREQ,IO,SRC8,DST8,DONECYC
OUTPUTS:     REQBUS, XDONE,DECB1,DECB2,DECS1,DECS2,DECD1,DECD2, R16S,
             R16D,R8S,R8D,SWAP

PROGRAM:

A: [00 00 00 00 0000 0] JUMP B;

B: IF STARTX*IO' THEN [10 00 00 00 0000 0] JUMP D;
     ELSEIF STARTX*IO THEN [00 00 00 00 0000 0] JUMP C;
     ELSE [00 00 00 00 0000 0] JUMP B;

C: IF DREQ THEN [10 00 00 00 0000 0]JUMP D;
     ELSE [00 00 00 00 0000 0]JUMP C;

D: IF GRANT*SRC8' THEN [00 01 01 00 1000 0]JUMP I;
     ELSEIF GRANT*SRC8 THEN [00 01 10 00 0010 0]JUMP E;
     ELSE [10 00 00 00 0000 0]JUMP D;

E: IF DONECYC*DREQ THEN [00 00 10 00 0010 1]JUMP F;
     ELSE [00 01 10 00 0010 0]JUMP E;

F: IF DONECYC THEN [00 00 00 01 0100 0]JUMP G;
     ELSE [00 00 10 00 0010 1]JUMP F;

G: IF DONECYC*BC0 THEN [01 00 00 00 0000 0]JUMP A;
     ELSEIF DONECYC*BC0' THEN [00 00 00 00 0000 0]JUMP H;
     ELSE [00 00 00 01 0100 0]JUMP G;

H: IF DREQ THEN [00 00 10 00 0010 1]JUMP E;
     ELSE [00 00 00 00 0000 0]JUMP H;

I: IF DONECYC*DST8 THEN [00 00 00 10 0001 0]JUMP J;
     ELSEIF DONECYC*DST8' THEN [00 00 00 01 0100 0]JUMP M;
     ELSE [00 01 01 00 1000 0]JUMP I;

J: IF DONECYC*DREQ THEN [00 00 00 10 0001 1]JUMP K;
     ELSE [00 00 00 10 0001 0]JUMP J;

K: IF DONECYC*BC0 THEN [01 00 00 00 0000 0]JUMP A;
     ELSEIF DONECYC*IO*BC0' THEN [00 00 00 00 0000 0]JUMP L;
     ELSE [00 00 00 10 0001 1]JUMP K;

L: IF DREQ THEN [00 01 01 00 1000 0]JUMP I;
     ELSE [00 00 00 00 0000 0]JUMP L;

M: IF DONECYC*IO*BC0' THEN [00 00 00 00 0000 0]JUMP L;
     ELSEIF DONECYC*IO'*BC0' THEN [00 01 01 00 1000 0]JUMP I;
     ELSEIF DONECYC*BC0 THEN [01 00 00 00 0000 0]JUMP A;
     ELSE [00 00 00 01 0100 0]JUMP M;
```

***Fig B—This high-level SAM specification** for the M_1 bus arbiter from part 1 of this series shows the proprietary IF-statement entry format for state transitions. To program for the chip's counter and stack, you must use assembly language.*

Because some PLD-design software packages perform minimization of logic functions, they can save you considerable time and effort.

macrocells, you would have to cascade macrocells to handle some of the state variables. A variable p-term device (22V10, EP1210) or a PLD with p-term redistribution (EP512) could handle this requirement directly. PLA devices would also provide a good result, because M_3 requires a total of 40 or fewer p-terms.

You implement asynchronous-state-machine state variables in combinatorial macrocells. Inserting intermediate states has the effect of adding another logic-array delay to your state transitions. **Fig 4** shows the PLD timing model for an asynchronous state machine. Note that the change in Q_0 takes the machine to an intermediate state and that this transition then triggers a change in Q_1 before the state machine makes the transition to the final state. This cascading means that a double state transition is actually occurring, and the extra T_{ARRAY} delay shown in the FREQUENCY equation is the result.

Delays for outputs from asynchronous machines are referenced to the appropriate inputs. Outputs typically become valid within one propagation delay (T_{PD}) of a new state's stabilizing. Because no central clock exists, you can't register outputs to minimize skews, as you can in synchronous machines.

If you're implementing an asynchronous state machine in which the input-to-output delays are critical, you may want to put those intermediate states to work. Normally, in a Moore machine, outputs are associated

```
              M3 State Assignment and Transition Equations

       State       State Variables
                 Q5 Q4 Q3 Q2 Q1 Q0
       ----------------------------
       IDLE         000000
       REQCYC       001100
       ARB          100100
       LOSE         000101
       BXFER        110000
       SXFER        100001
       FINISH       100000
       PEN          100010
       ------------------
       INTER-       000100
          MEDIATE   101100
             |      100101
             |      000001
             V      100011
                    110010
                    000010
                    010000
                    110100

       Q0 = (10010X*ARB/-GNT'*WIN' + 000101* (BUSREQ + BRSTREQ) +
            10010X*BUSREQ*WIN*ARB/-GNT + 100001)*CHRESET'        (5 TERMS)

      Q1 = (1100X0*ARB/-GNT*FAIR*BRSTREQ + 100010 + 1000X1*ARB/-GNT)*CHRESET'
                                                              (3 TERMS)

    Q2 = (000X00*(BUSREQ+BRSTREQ) + X01100 + 100100 +
         100101*ARB/-GNT'*WIN' + 100101*ARB/-GNT*(BUSREQ+BRSTREQ) +
         000101)*CHRESET'                                     (8 TERMS)

    Q3 = (00X100*(BUSREQ+BRSTREQ))*CHRESET'                   (2 TERMS)

    Q4 = (1X0100*BRSTREQ*WIN*ARB/-GNT + 110000*FAIR'*BRSTREQ' +
         110000*(ARB/-GNT+FAIR*BRSTREQ') + 110000*PREIN')*CHRESET'
                                                              (5 TERMS)

    Q5 = (X01100*(BUSREQ+BRSTREQ) + 100100*ARB/-GNT'*WIN' +
         10010X*ARB/-GNT*(BUSREQ+BRSTREQ) + 1X0100*BRSTREQ*WIN*ARB/-GNT +
         1100X0*(ARB/-GNT+FAIR*BRSTREQ') + 1X0000*(FAIR+BRSTREQ) +
         100010*PREIN + 100101*BUSREQ*WIN*ARB/-GNT' +
         1000X1*BUSREQ + 110000*PREIN)*CHRESET'              (14 TERMS)
```

Fig 3—Given the state assignments in Fig 2b, *these transition equations result for M_3. M_3 is a Moore machine.*

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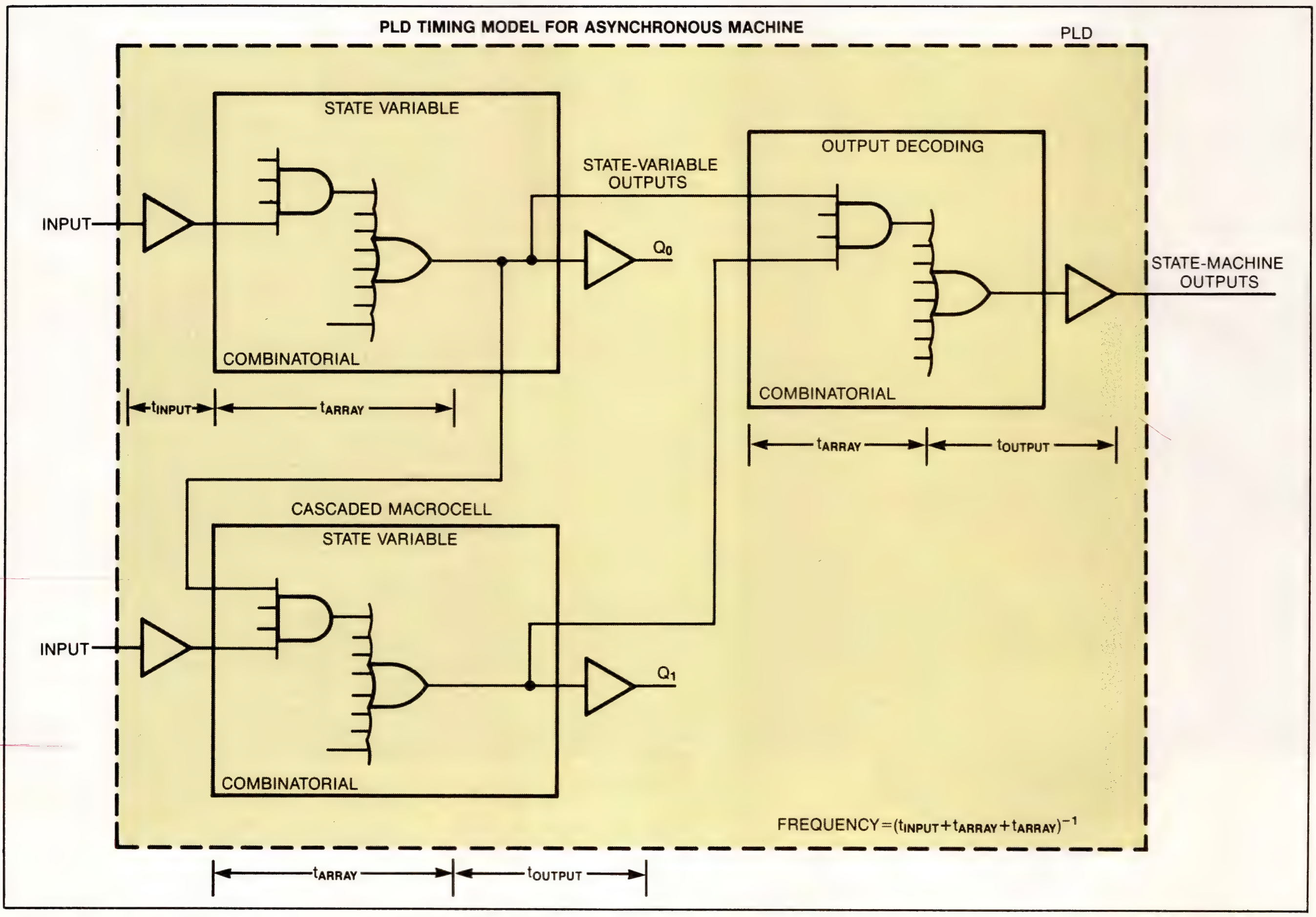

***Fig 4—When you use this PLD timing model to calculate** assignments in Fig 2b, these transition equations result for M_3. M_3 is a Moore machine.*

with primary states. If you find that an output can't tolerate the added delay of the intermediate state, you can activate the output at both the intermediate state and the primary state. This assignment eliminates the added logic-array delay in generating the output, so it effectively performs an output look-ahead. Be careful, though: If you use an intermediate-state code in more than one place (as in **Fig 2b's** state diagram of M_3, which has state 100101 in more than one place), you'll need to decode the intermediate state *and* the inputs to guarantee that the output will be correct.

Given this model, you can see that a PLD that implements M_3 will be able to operate at

$$\text{Frequency}=1/T_{INPUT}+(2\times T_{ARRAY}).$$

Therefore, a typical PLD in which T_{INPUT}=5 nsec and T_{ARRAY}=20 nsec will operate at approximately 22 MHz. PLDs having a faster speed grade would give correspondingly faster frequencies. **EDN**

Author's biography

Stanley Kopec is manager of product planning for programmable logic at Altera Corp in Santa Clara, CA. He has been with Altera for three years. Prior to joining Altera, Stan worked for Exel Microelectronics, where he was in charge of μP-peripheral development. He holds a BSEE from the State University of New York at Buffalo and an MSEE from the University of Illinois. In his spare time he enjoys racquetball, skiing, and reading.

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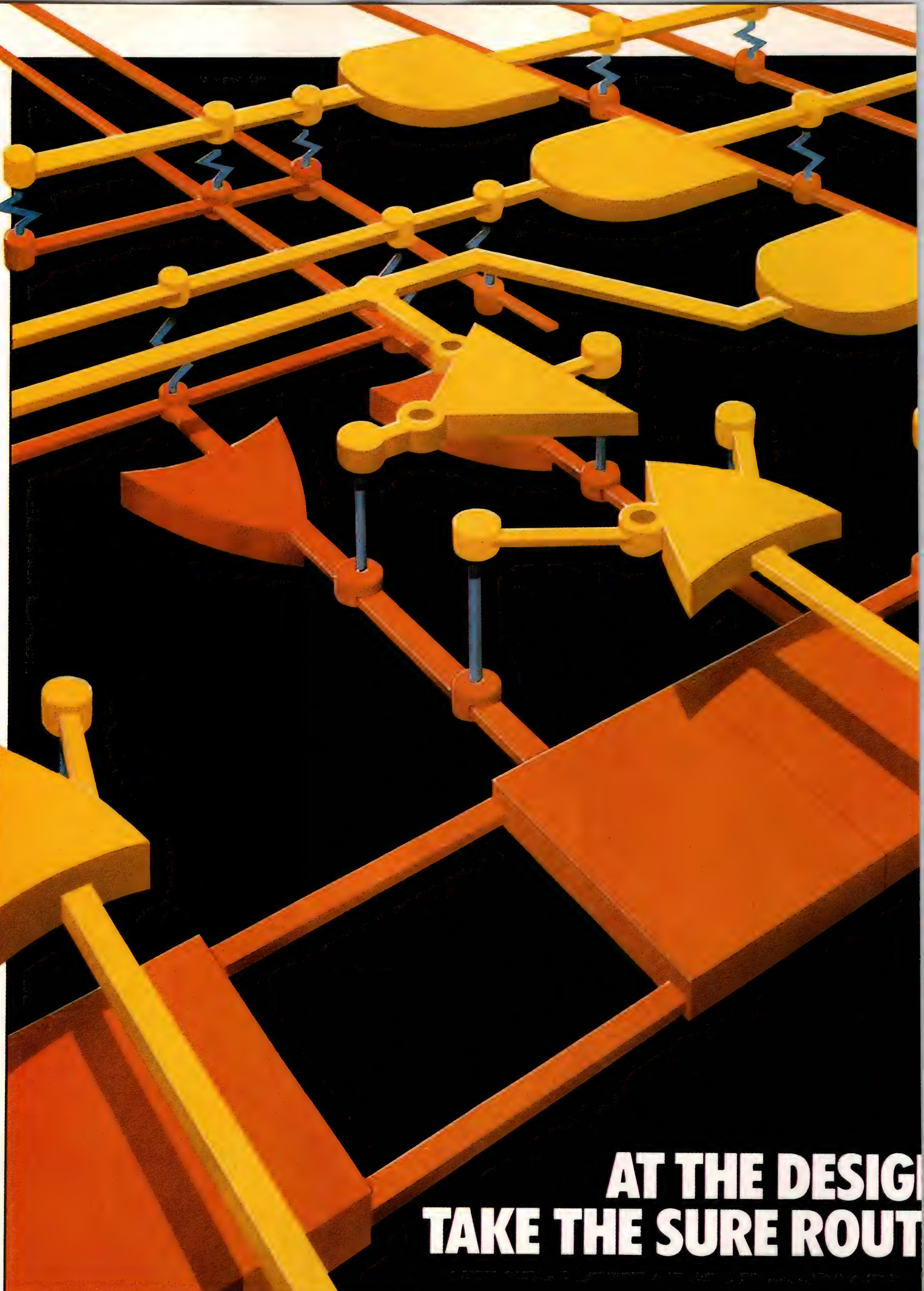

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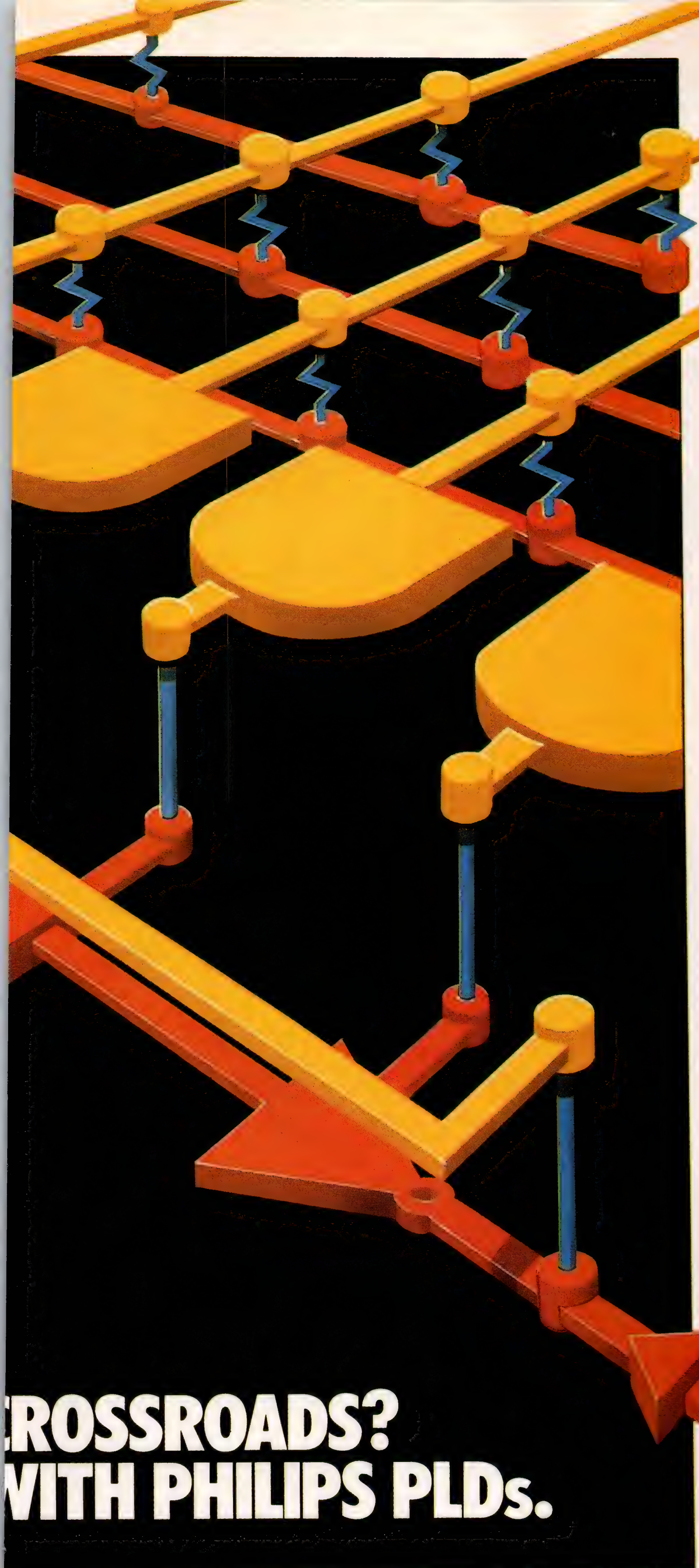

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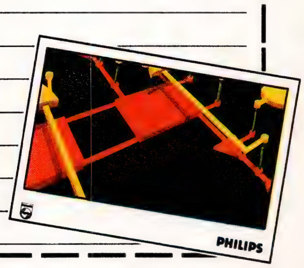

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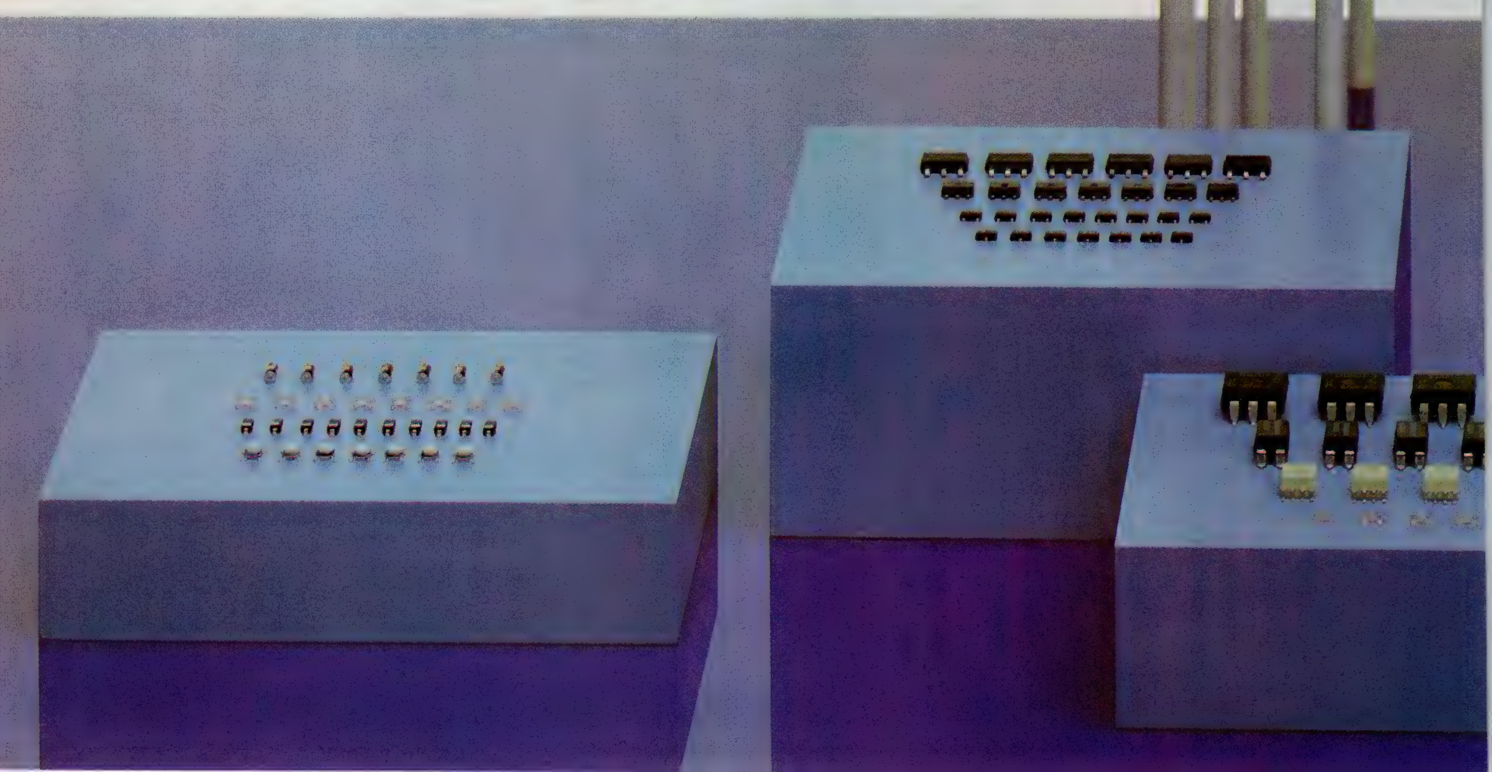


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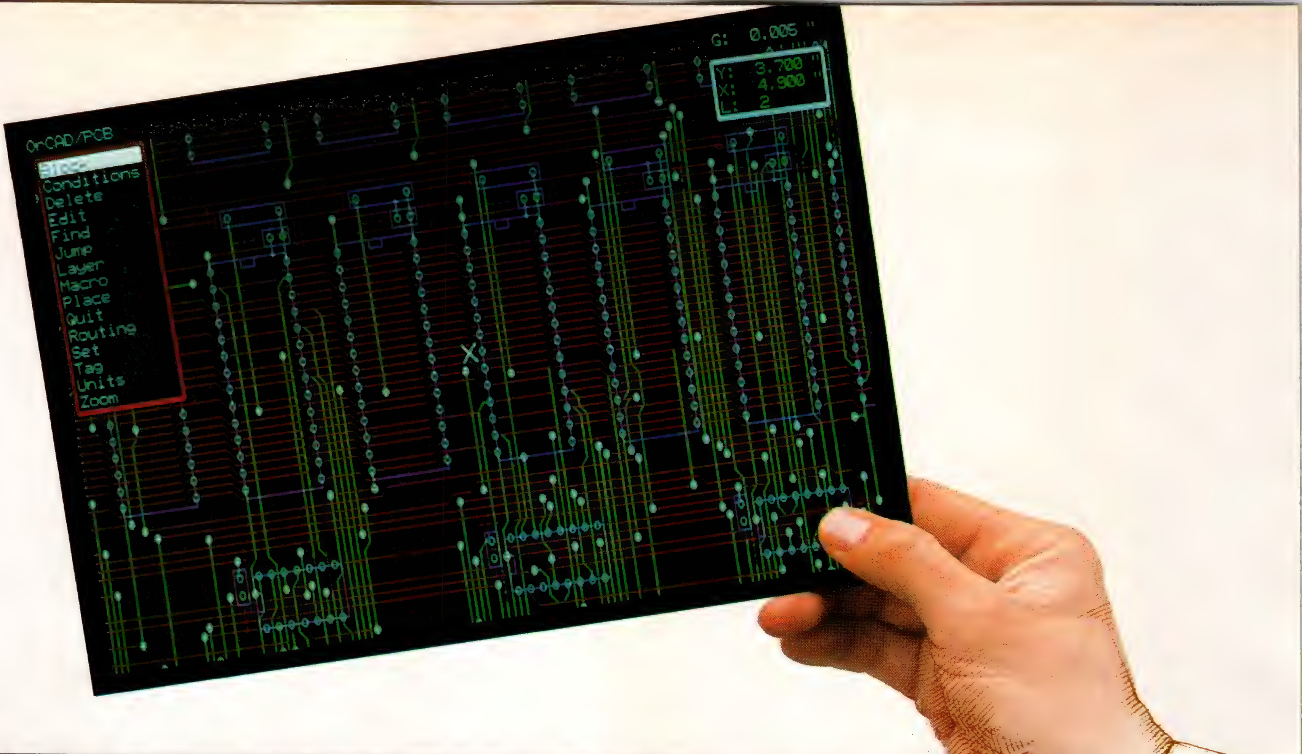
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Back-to-basics approach yields stable references

Achieving the accuracy and stability that IC voltage references promise isn't necessarily a "piece of cake," but if you return to your EE roots and do a little old-fashioned analog-circuit analysis, you can obtain impressive results.

Ron Knapp, *Maxim Integrated Products*

Analog-IC manufacturers make it *look* simple to achieve the voltage-reference accuracy and stability that used to present major challenges for circuit designers. Today, obtaining stability of a few parts per million per degree should be a routine task. Nonetheless, ignoring facts of life such as noise and I·R drops can transform a seemingly simple job into one as complex as that faced by reference designers 20 years ago. Attention to circuit basics can make obtaining precise rock-solid reference voltages in the late 1980s as uncomplicated as the vendors of the ICs intend it to be.

Selecting a low-temperature-coefficient, precision voltage reference starts with careful consideration of your noise requirements. If the reference is too noisy, the highest dc accuracy and the cheapest price won't mean anything. Determine the signal-to-noise ratio your application requires. If you intend to use the reference with an A/D or D/A converter, the reference noise should be less than 1/10 the resolution. For example, a 12-bit ADC with a 0 to 10V input has a 1-LSB resolution of 2.44 mV. The maximum noise from the reference should be no more than 240 μV p-p. In this case, a bandgap reference such as an REF01 or AD581 will suffice. For a 14-bit converter with an LSB size of 610 μV, a noise limitation of 60 μV will require an AD2700, MAX670, or equivalent.

Often, you can lower the wideband noise with a large capacitor placed on the reference-device output. A 10-μF capacitor is large enough to prevent oscillation problems and will typically decrease the high-frequency noise (above 1 kHz) by a factor of 3 or 4. Some references, like the AD584, have noise-reduction pins that allow you to add an external capacitor. A smaller capacitor (0.01 μF) placed in parallel with the feedback resistor (if the inverting input of the reference amplifier is available) will filter the noise from both the reference device and the amplifier, but will also adversely affect the turn-on time and the circuit's response to load changes. Nevertheless, there is little you can do about low-frequency noise, and therefore most reference data sheets place great importance on noise in the 0.1- to 10-Hz band.

Thermal effects take second place

Taking into account noise considerations, the second most important spec of a voltage reference is the temperature coefficient, or TC. Don't ignore initial

Ignoring facts of life like noise and I·R drops can turn what appears to be a simple job into a complex one.

accuracy, though, or take it too lightly, thinking that you'll be able to adjust it. Remember that any components you add can jeopardize the TC, long-term stability, and reliability—all it takes is one component that drifts out of calibration. For example, using a reference's trim-adjust feature or scaling its output with an external gain stage will probably affect the TC.

To set the gain of an op amp, you should use TC-matched thin-film resistor networks. When you use separate RN55D metal-film resistors with TC specs of ±50 ppm/°C, you introduce a TC error of 100 ppm/°C if one resistor TC is +50 ppm/°C and the other is −50 ppm/°C. The fine-trim adjustment of the AD2700 is somewhat interactive with the TC; 1 mV of adjustment changes the TC by 4 μV/°C or 0.64 ppm/°C referred to the output. The best advice to follow about reference trim adjustment is "don't do it." It is much better to calibrate the gain elsewhere—at the D/A converter, for example. Better yet, make gain adjustments in software. If there is a temperature-independent gain trim elsewhere in the system, you can use the AD2700's fine-trim output-voltage adjustment to change the device's TC (and, incidentally, affect its output voltage).

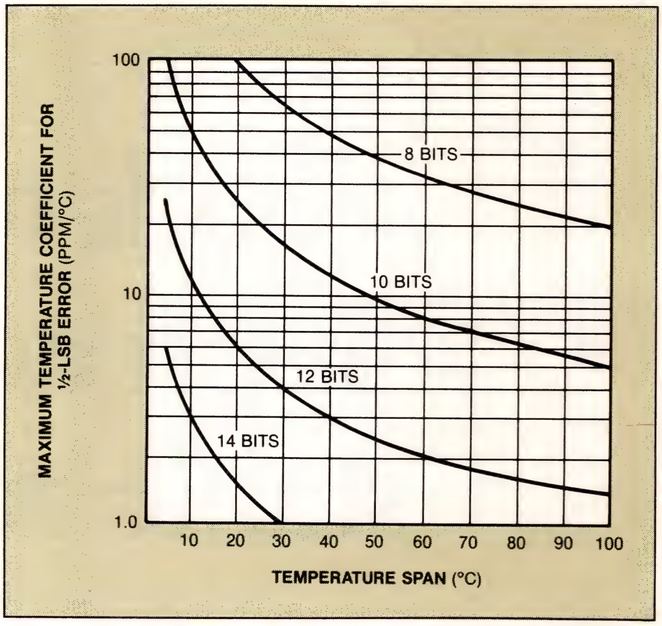


Fig 1—Increasing the resolution *of an A/D or D/A converter decreases the temperature range over which it delivers absolute accuracy comparable to its resolution.*

High-resolution converters need TLC

Most high-resolution converters, such as 16-bit DACs and ADCs, guarantee linearity consistent with resolution, but rarely do they guarantee absolute accuracy, which includes gain error, to that level. Because the gain accuracy depends primarily on the accuracy of the voltage reference (whether internal or external), the temperature coefficient of the reference determines the useful temperature range for converter accuracy (**Fig 1**). Applications where absolute accuracy is critical include weighing scales, data-acquisition measurement systems, automatic test equipment (ATE), and laboratory instruments (such as DVMs and programmable voltage standards).

First, consider a 12-bit-system example. A 12-bit A/D converter with its linearity specified to ±½ LSB requires a reference with a TC of no more than 2.67 ppm/°C from 25 to 70°C to maintain a gain accuracy within ½ LSB, or 1.2 mV out of 10V FS. A suitable reference would be the AD2710KD, which is specified to 2 ppm/°C max from 0 to 70°C.

For a 16-bit system, you can use a reference guaranteed to 1 ppm/°C, like a MAX671 or an AD2710LD, to obtain true 16-bit absolute accuracy over the 7.5°C range from 25 to 32.5°C. Between these temperatures, the output of the reference changes no more than 75 μV—an amount equivalent to less than ½ LSB on a 16-bit, 10V FS converter.

Most voltage references on the market produce a single-ended output between V_{OUT} and GND, as in the AD2700, REF01, AD580, AD581, and AD584. In these types of devices, I·R voltage drops can cause errors that can spoil the accuracy of the output voltage. The reason is that the load current must pass through the V_{OUT} pin and the quiescent supply current must pass through the GND pin (**Fig 2**). If the output happens to be sinking current—for example, if the load is connected between V_{OUT} and V^+ as in **Fig 3**—then the load current also returns through the GND pin. In most cases, however, the load is connected between V_{OUT} and GND; the load current flows into the reference from V^+ and out to the load through the V_{OUT} pin. In these cases, the I·R drop on GND won't disturb the output voltage, but the I·R drop on the V_{OUT} pin will always remain.

You can minimize single-ended output errors by using a device whose package incorporates internal Kelvin connections (that is, separate force and sense lines) to connect the die to the package pins (**Fig 2**). Running both force and sense bond wires internally from the chip to the output pin places the "force" bonding wire's resistance inside the output amplifier's feedback loop. This technique in effect eliminates connection resistance except for that of the pin itself and

that of the wiring or metal trace between the output and the load. With many references operating at full output current, even if you connect the load directly to the pin, the voltage drop in the pin resistance itself is large enough to equal the initial accuracy spec.

Small errors add up

For example, the AD2710LD has an initial accuracy of 10.000V ±1 mV max. The device is enclosed in a 14-lead ceramic sidebrazed DIP that can have a pin resistance of 0.05Ω **(Fig 2)**. If your circuit draws the full output current of 10 mA, the resulting voltage drop in series with the load will be 0.5 mV—half the initial accuracy spec. This drop has the effect of lowering the output voltage to 9.9995V (assuming that the factory set it to exactly 10.0000V with no load).

If you connect the load to V^+ as in **Fig 3,** the error will be twice as great, because the GND I·R drop is additive. The result is a further decrease in load voltage, to 9.9990V. In fact, the output-lead resistance is the dominant contribution to the load-regulation spec of 50 μV/mA, which is equivalent to 0.05Ω. The I·R-induced errors can expand into several millivolts if there is any length of wiring or pc-board trace that measures a few tenths of an ohm.

For constant-current loads, it's possible to simply adjust out the errors caused by I·R drops. However, the TC of the reference may be unacceptable because the TC of the pin resistance is too high. Gold has a TC of 4000 ppm/°C, or 0.4%/°C. With this TC, the 0.05Ω resistance in the above example would increase by 40% between 25 and 100°C. At 100°C, the resistance is 0.07Ω and produces a 0.7-mV error at a load current of 10 mA.

Sense at the load

A voltage reference can easily eliminate all the problems associated with I·R drops if it uses Kelvin outputs with separate force and sense pins joined at the load. The sense pin carries only a small, constant current, such as that which flows in the gain-determining feedback resistors. The force pin carries all of the variable load-dependent current. You close the feedback loop at the load by connecting the force and sense pins there; that is, you place the wiring and pin resistances inside the feedback loop.

Because of limitations on the number of package pins, some references provide only one GND pin and offer Kelvin connections only on the output. This setup is adequate if the output sources current but does not sink it, as is true in the majority of applications. The MAX670 and MAX671 contain full Kelvin connections

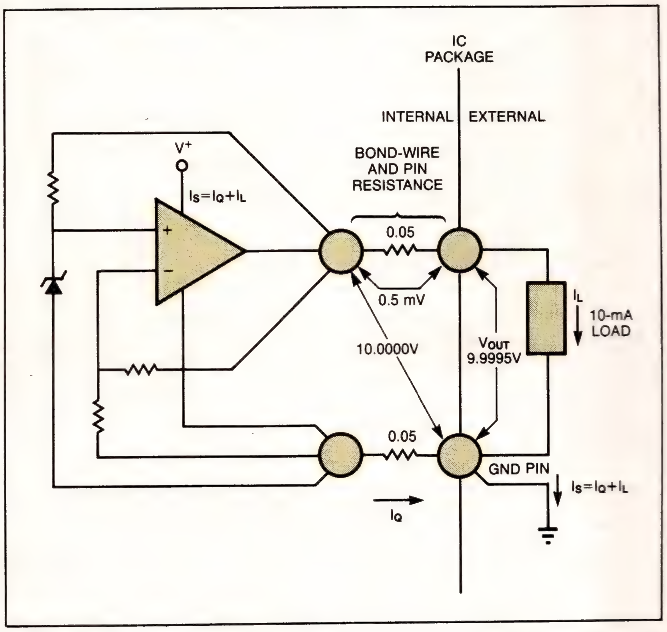


Fig 2—When this reference supplies current *to a load, voltage drops inside the package are inside the feedback loop and have little effect on accuracy. The voltage drop across the package's output pin can be significant, however.*

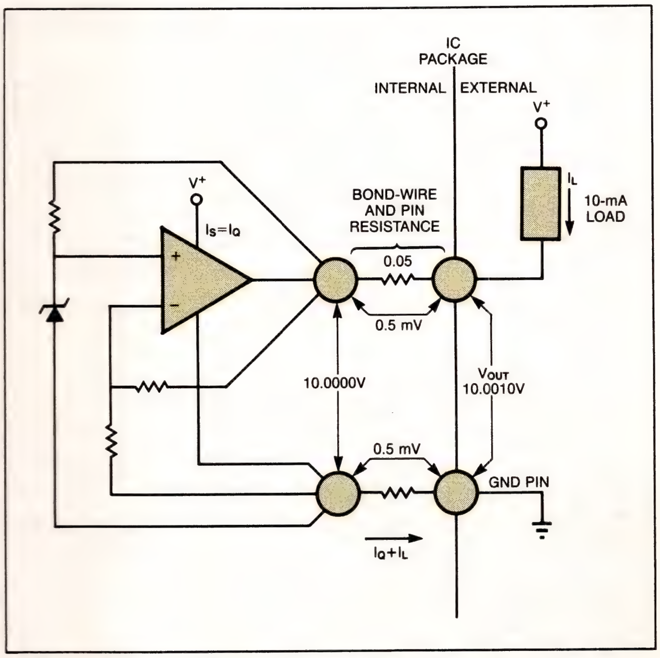


Fig 3—If a reference sinks current *into its output from the positive supply, both the voltage drop across the package's ground pin and the drop across its output pin will affect accuracy.*

Don't take the initial accuracy too lightly, thinking that you'll be able to adjust it.

on both output and GND (**Fig 4a**). These devices can source or sink 10 mA.

Why are Kelvin output connections so important? First of all, they make the voltage reference easier to use: You can preserve accuracy without providing extra-wide printed-circuit traces or limiting the load current or the length of the wire that carries it. (You do, however, need to consider the possibility of loop instability caused by the inductance of the load-current-carrying wires and capacitive loading of the feedback network.)

Fifty milliohms *can* be a big deal

D/A and A/D converters with 12- to 16-bit resolution often require separate voltage references. In the case of a 16-bit converter, if the full-scale input equals 5V, 1 LSB has a value of 76.25 μV. As good as the AD2700 is, with a load-regulation spec of 50 μV/mA, it takes only a 1.5-mA change in the output current to cause a 1-LSB error. Such a 1.5-mA change means that, if you were to use a reference such as the REF01, with a load-regulation spec of only 1 mV/mA, the result would be a 20-LSB error. In a 12-bit, 10V-FS converter, the same 1.5-mA reference-current change causes the REF01's output voltage to change by more than ½ LSB. Fortunately, except for transients that occur when the converter's code changes, the reference input current of an ADC or DAC is normally constant.

Sometimes, though, you must switch the A/D converter between a unipolar 0 to 10V range and a bipolar −10 to +10V range. You can do so by using relays to switch the converter's bipolar-offset-resistor input to GND or to the voltage-reference output. This arrangement causes the load on the reference to vary by 1 mA. The MAX670's Kelvin outputs alleviate concern over output-voltage changes caused by such output-current changes.

Buffering—analgesic for pain of high current

The MAX670 and the MAX671 are unusual in the way that their Kelvin sense lines are further divided between two separate pins (**Fig 4a**). This arrangement allows you to add an output buffer transistor or amplifier for higher current. It also allows you to place the added components within the reference feedback loop and thus maintain the specified performance at the load (**Fig 4b**). For example, an LH0101, together with a MAX670, can supply 10V at 2A with a 3-ppm/°C TC. In this way, the MAX670 can serve as an ultrastable, low-noise power-supply regulator with an output current ranging from hundreds of milliamps to a few amps, depending on the external buffer components.

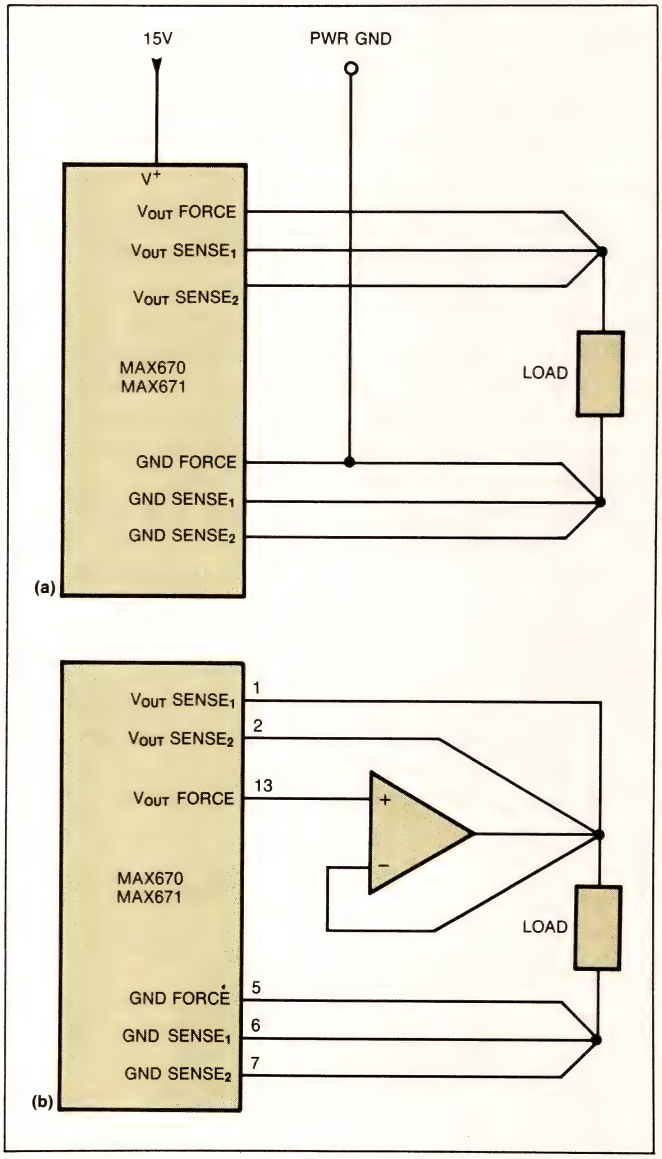


*Fig 4—**By providing a pair of sense terminals** for both the output and ground signals **(a)**, this reference can compensate for voltage drops outside as well as inside the package **(b)**. The configuration also allows you to enclose a high-current output buffer within the feedback loop.*

You can use an amplifier to buffer references without Kelvin connections, but the voltage at the load is subject to added errors such as offset, drift over temperature, output-impedance-induced voltage drops, and voltage variations caused by line regulation. If you know the load current to within ~20%, you can supply high current regardless of the type of reference, even if

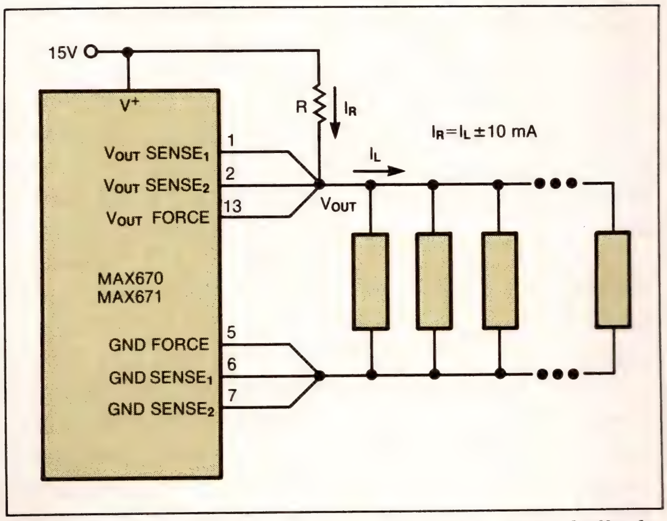


***Fig 5—A pullup resistor** acts as a poor man's output buffer by delivering most of the load current. Even though it delivers a small fraction of the load current, the reference still controls the output voltage.*

it is one with a single-ended output (**Fig 5**). In such a special case, you can use a pullup resistor to supply the nominal load current from V^+ to V_{OUT}. The reference output then only needs to sink or source the error current—the difference between the actual load current and that supplied by the resistor. Most IC-op-amp outputs supply at least ±10 mA. Ideally, if the pullup current exactly equals the load current to ground, the output current from the voltage reference will be zero. When using references like the REF01, which can source current but cannot sink it, you must guarantee that the current in the pullup resistor is less than the load current, so that the reference always supplies some current. The REF01 supplies 10 mA to ground, so you should select the pullup resistor to supply 5 mA less than the load current. That way, the REF01 will nominally supply 5 mA, a value in the middle of its range.

This technique is prevalent in ATE, where one reference supplies the reference input to perhaps dozens of D/A converters, which set the voltage or current of the pin drivers that supply signals to the device under test. A similar situation arises in drift testing large numbers of D/A converters in a temperature chamber; a reference outside the chamber drives the reference input of all of the converters.

All in all, there are three advantages to using a pullup resistor to boost a reference's output-drive capability: Adding a single passive component is simple and cheap; you preserve the accuracy and TC performance of the reference without resorting to Kelvin connections; and you don't need extra supply current (as you would if you used a buffer).

Why not design your own?

Voltage references seem like simple circuits, so you might be tempted to design your own with discrete components, but you should consider the tradeoffs carefully. To make a bandgap reference like the REF01, for instance, you need two transistors carrying equal currents with an 8:1 current-density ratio. In other words, one transistor must have 8× the emitter area of the other. Matched pairs that have this area ratio are not commonly available, but you could use a pair of identical devices and set the current ratio with resistors, except that the TC of the resistors must match as do the TCs of R_1 and R_2 in **Fig 6.** In addition, you still have to amplify the 1.2V bandgap voltage, something that requires an op amp with matching gain resistors (R_5 and R_6 in **Fig 6**).

If you want to construct a reference similar to the AD2700 (**Fig 2**), you can do so with a 1N829 5-ppm/°C zener diode and an op amp, but again don't forget the task's nontrivial nature. First of all, the diode's several-dollar price tag is a significant expense. And, in discrete form, the best temperature-compensated diodes have TC specs higher than the AD2700 spec. Assuming you can accept 5 ppm/°C, however, you'll need a low-

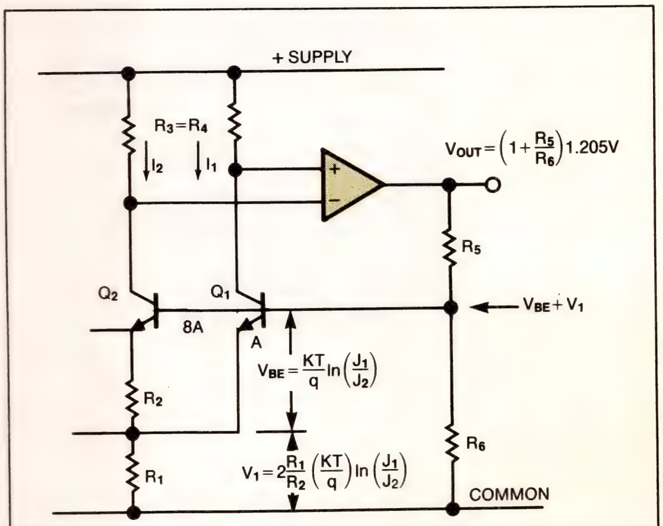
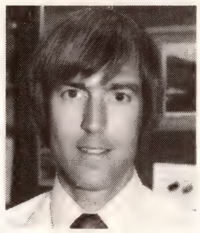


***Fig 6—A bandgap voltage reference** generates the sum, $V_{BE}+V_1$, in which the two voltages have equal and opposite temperature coefficients. The amplifier then raises the sum to a more convenient voltage level.*

drift op amp. The spec of 5 ppm/°C translates into 50 μV/°C, and therefore you'll need an op amp like the OP07, with an offset voltage drift significantly smaller than 50 μV/°C. The OP07's 2.5-μV/°C drift, when multiplied by the required gain of 1.59, contributes 0.4 ppm/°C (10V/6.3V·0.25 ppm/°C=0.40 ppm/°C). You can reduce this drift further by substituting a MAX400 op amp: It has a 0.3-μV/°C maximum offset-voltage drift spec, which translates to only 0.05 ppm/°C. Assuming that you use a thin-film resistor network, you should allow a 0.5-ppm/°C tracking TCR. You should also be aware of thermocouple effects of as much as several μV/°C, a result of interconnections between different metals. The thermocouples' sensing and reference junctions are at slightly different temperatures because of gradients across the board. Finally, if you add up the cost of the components and the time to build, test, and calibrate the circuit, you can easily appreciate the value of purchasing a complete, tested, and guaranteed precision voltage reference. **EDN**

Author's biography



Ron Knapp is a senior member of the technical staff at Maxim Integrated Products (Sunnyvale, CA). He holds a BS in systems engineering from Boston University and an MSEE from Worcester Polytechnic Institute. He is vice president of the Northern California Chapter of The International Society for Hybrid Microelectronics (ISHM). In his spare time, Ron enjoys flying and sailing.

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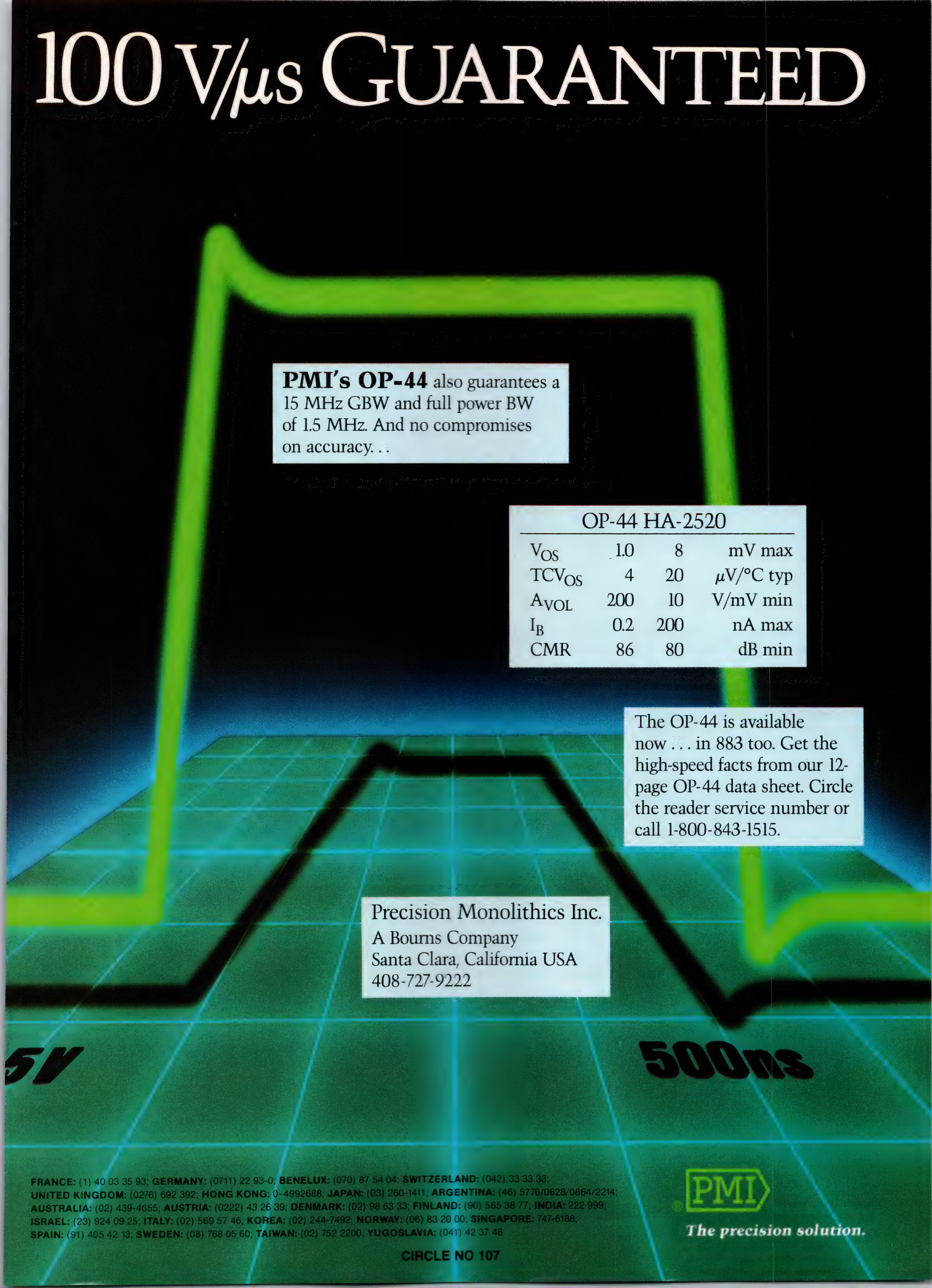

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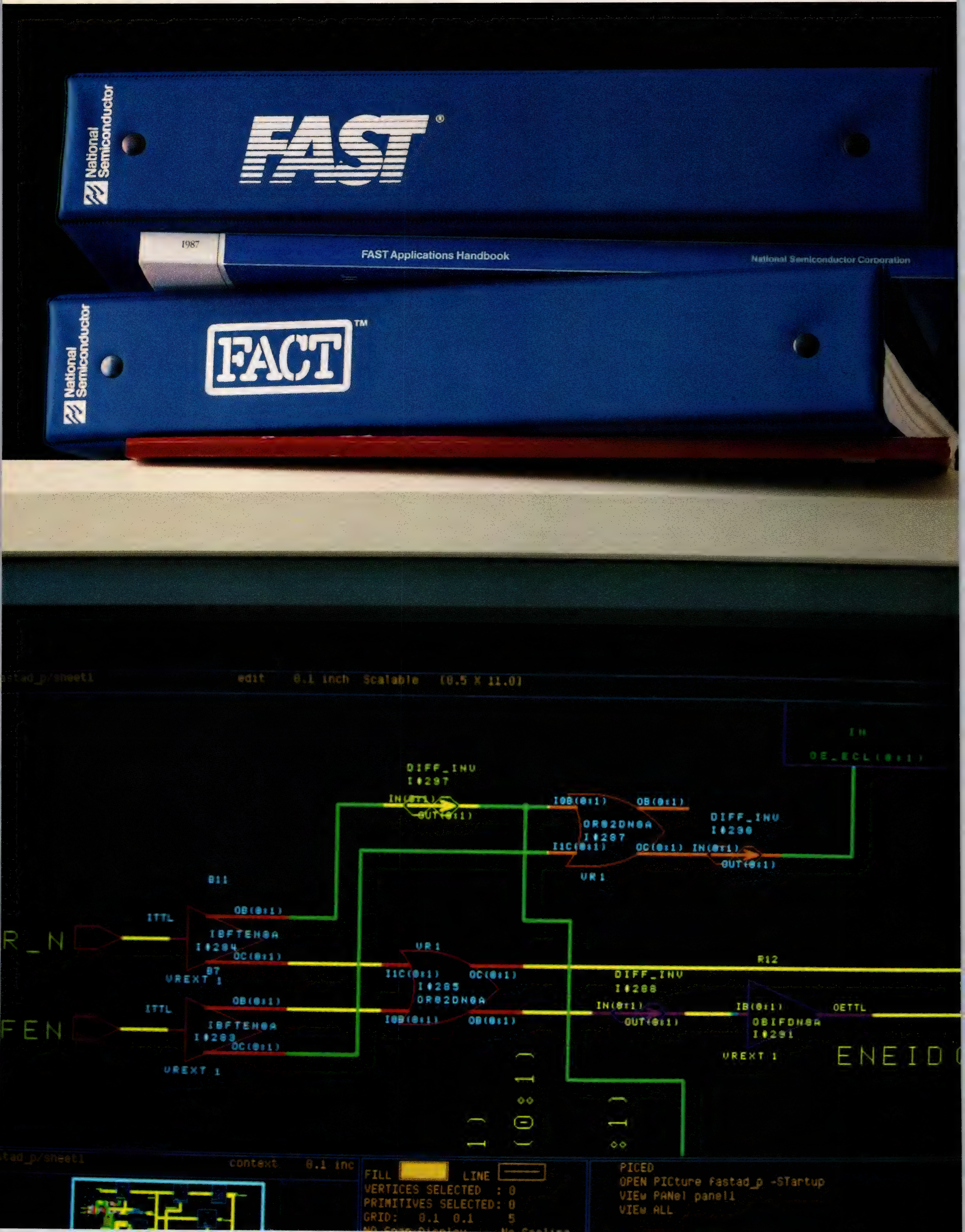

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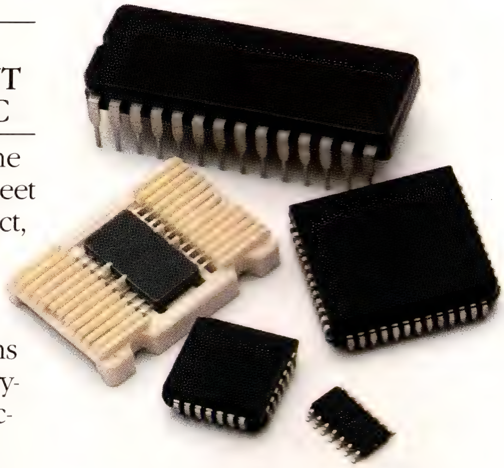

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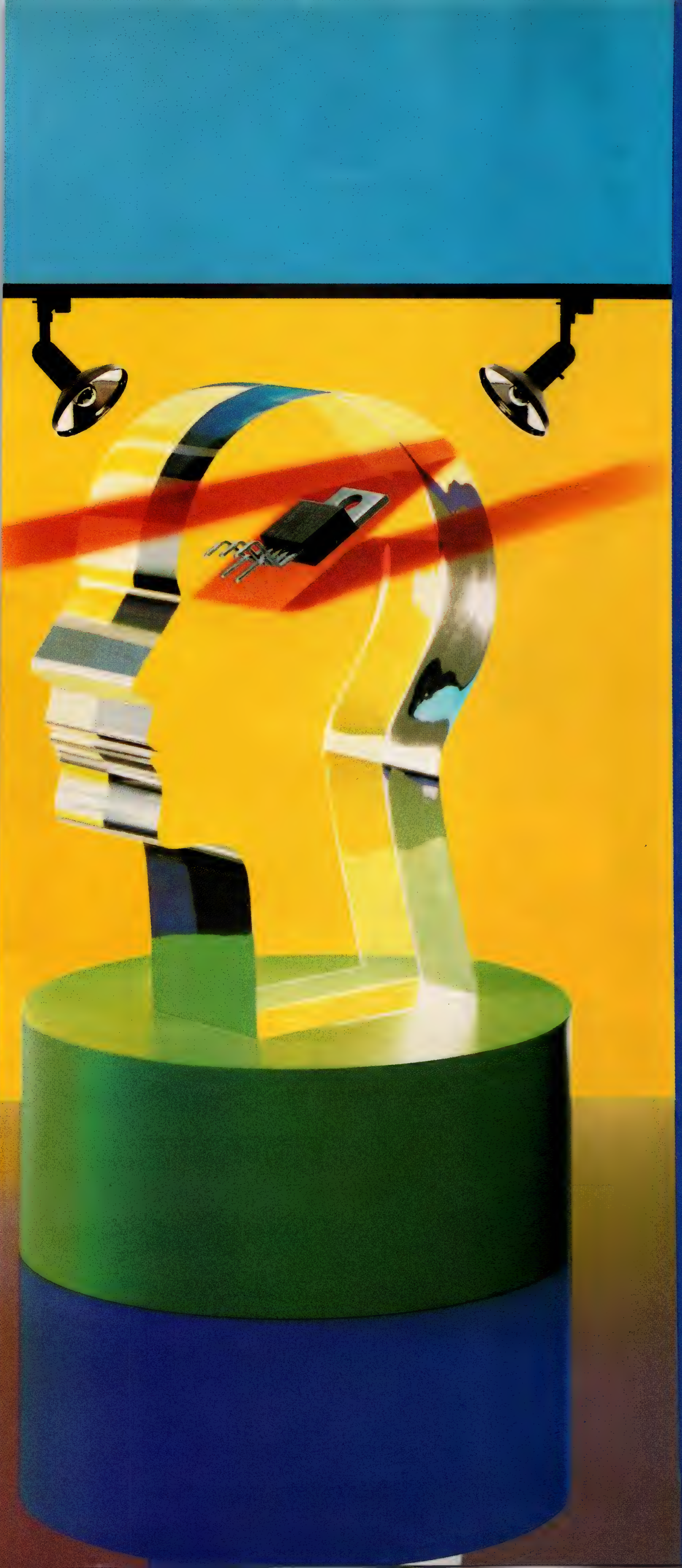

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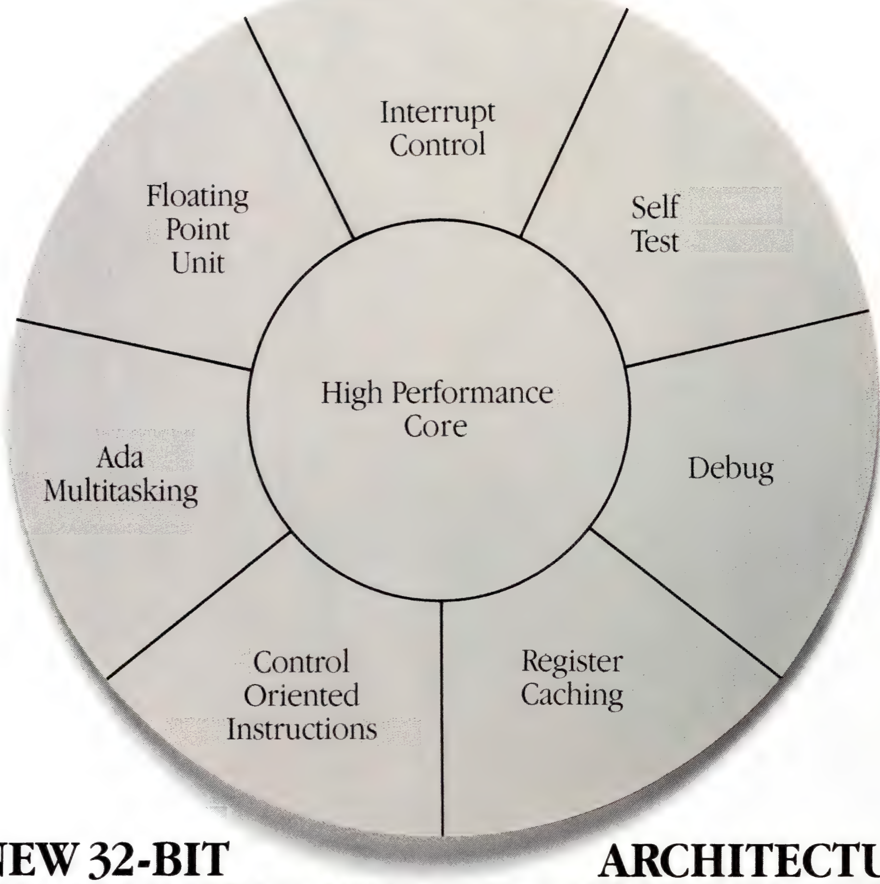

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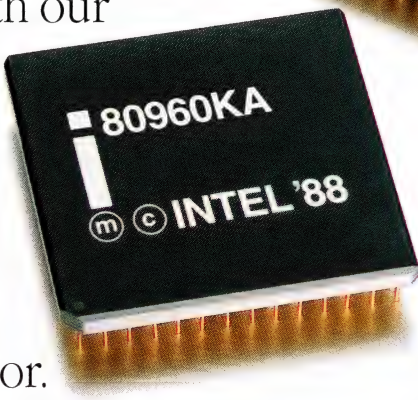

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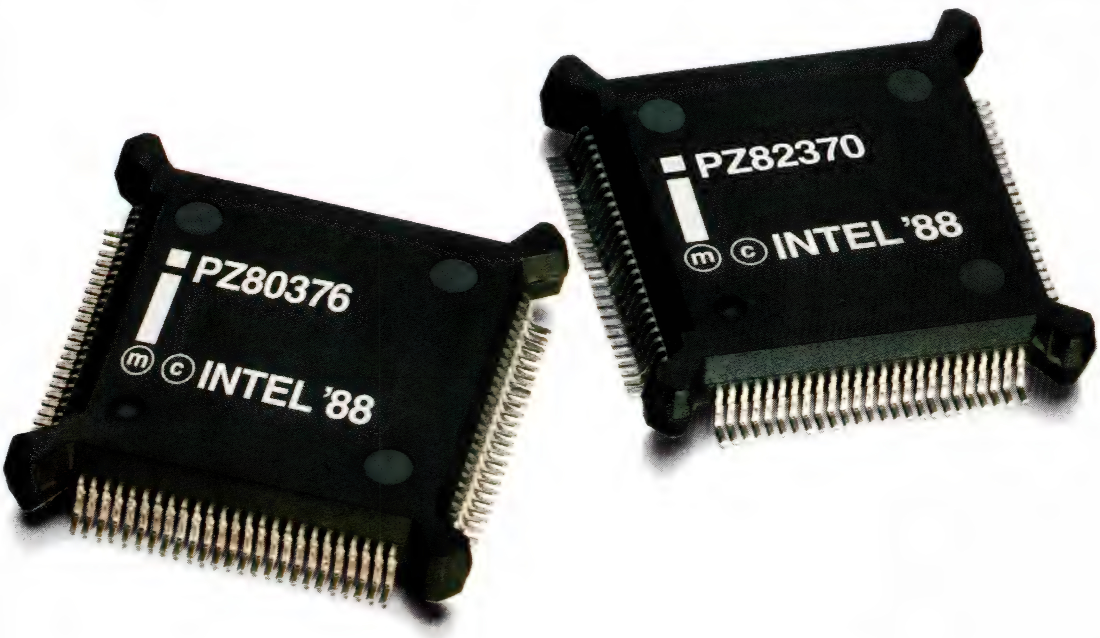

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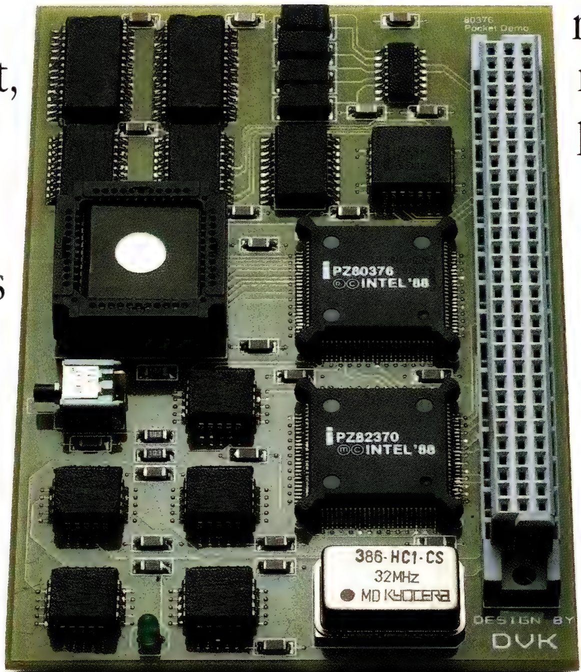

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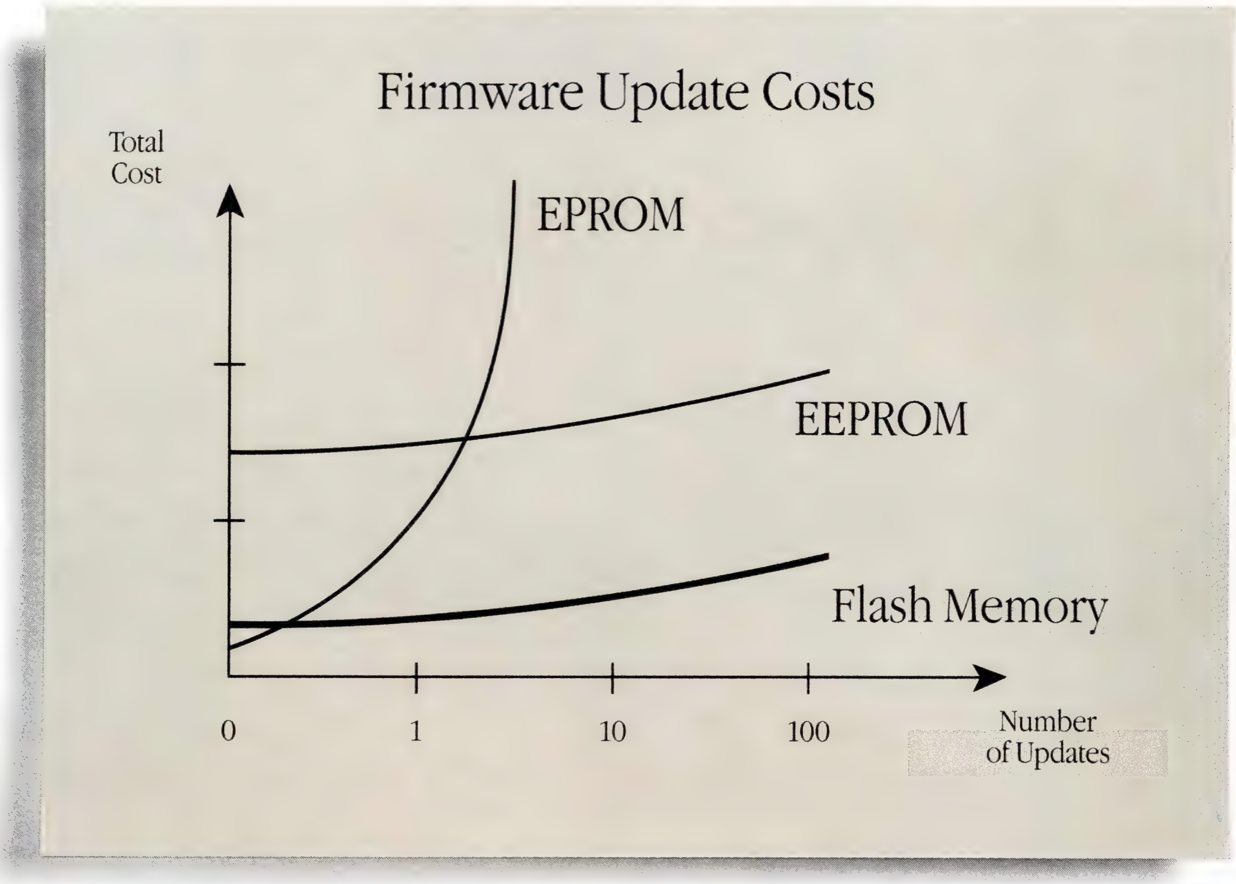

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Now, we've invented a way to incorporate electrical erasure into our proven EPROM process. We call it ETOX™ (EPROM Tunnel Oxide) Flash technology. And we think it's a major breakthrough in non-volatile memory technology. ETOX Flash memory allows you

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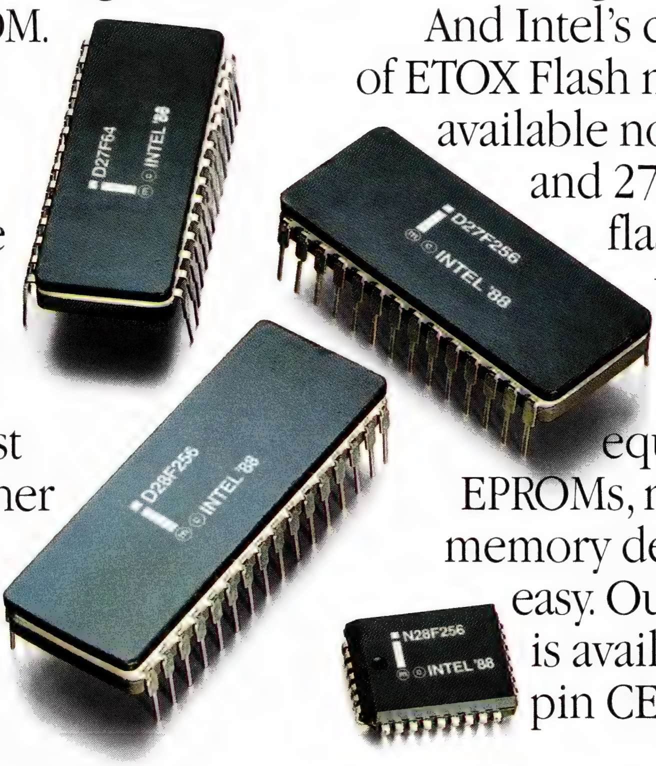

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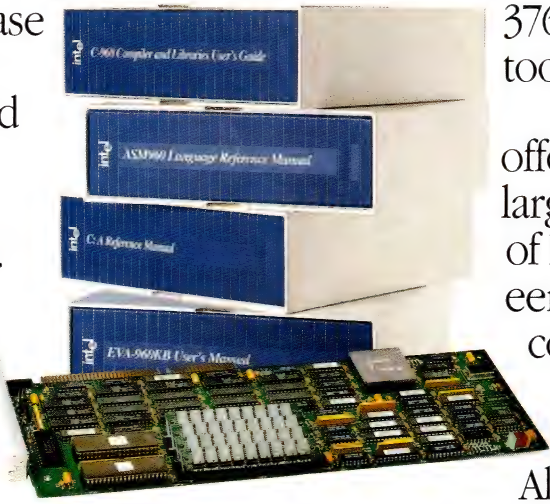

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Tape drives can work like disk drives if you use SCSI bus

The SCSI Common Command Set lets you read and write tape storage in just the same way that you handle disk storage. Intelligent controllers eliminate the need to learn the details of tape formats and access commands. What's more, you don't have to bother with separate software for your tape drivers.

Tony Kozlowski, *3M Company*

When building a microcomputer system, you can save a considerable amount of development time and effort if you incorporate tape drives that respond to the SCSI random-access Common Command Set (CCS). These tape drives can use the same software device drivers (with only minimal modification) as the disks do. In addition, you don't need to learn complex sequential-access commands to make optimum use of the tape medium—you can rely on the intelligent controller to translate the commonly known SCSI commands into the detailed hardware commands needed by tape drives. In effect, the SCSI controller makes a tape device look like just another disk drive to the host computer.

Using the same command set for both disk and tape storage devices is particularly important to designers of multiuser microcomputer systems. Since an IBM PC/XT seldom has more than 30M bytes of hard-disk storage, you can use standard 360k-byte floppy disks as the backup and archiving media, although the process is somewhat tedious. But in microcomputers of the PC/AT or 80386 class, or 68020 systems running Unix, storage capacities start at 30M bytes for a single-user system and may reach 300M or more bytes in a multiuser system or network file server. In such situations, floppy disks are no longer practical for backup.

Until recently, in order to use tape drives, you had to fully understand the complexities of tape formats as well as their relatively obscure command sets for sequential access. Fortunately, the current generation of both hard-disk drives and cartridge tape drives (such as 3M's MCD-40/SCSI) frequently incorporate intelligent controllers that respond to the SCSI commands for random-access devices.

SCSI bus concept is simple

There's nothing mysterious or complex about mixing tape and disk storage devices on the SCSI bus. The only extra hardware you'll need is a host adapter that plugs into the host computer's bus. This adapter translates the host's I/O requests into standardized SCSI signals. At the peripheral end of the SCSI bus, an intelligent controller (usually supplied as an integral part of the drive electronics) translates the standardized SCSI signals into the detailed command sequences that actually control the peripheral. Within the host, the software drivers let the host send file-oriented I/O requests across the bus to a peripheral's controller that

There's nothing complex or mysterious about mixing tape drives with disk drives in a SCSI bus system.

understands commands such as Read, Write, and Seek.

The primary drawback to this type of setup involves speed. Designers whose main concern is a high data-transfer rate have been known to complain that the double translation process (from host command to SCSI command, and then from SCSI command to device command) is inefficient. It's true that other buses such as ESDI (Enhanced Storage Device Interface) and IPI (Intelligent Peripheral Interface) can provide transfer rates that exceed 10M bytes/sec, but these buses require a separate controller in the host for each type of storage device. The maximum SCSI transfer rate is currently around 1.5M bytes/sec, but if you opt for that slower rate, you'll gain some system flexibility.

Bus configuration can be simple or complex

In small systems, the SCSI bus provides data transfers between a single host computer, called the initiator, and as many as seven peripheral devices, called targets, which include tape and disk drives, printers, plotters, and others **(Fig 1)**. Multiprocessor systems **(Fig 2)** can not only establish communication from any processor to any peripheral, but also from host to host, because the host adapter in each host is itself a SCSI device and can be a target as well as an initiator. Two peripherals (targets), however, cannot normally communicate with each other, and only two devices (one initiator and one target) can communicate with each other over the bus at any one time.

Take some tape features into account

Regardless of the architecture of the host and the nature of the specific peripheral devices, the basic SCSI configurations and the rules for implementing them remain constant. But you must still keep in mind some inherent differences between disk and tape; if the sequentially-oriented tape is to appear to the system like a random-access device, you must make these differences completely transparent to the file system.

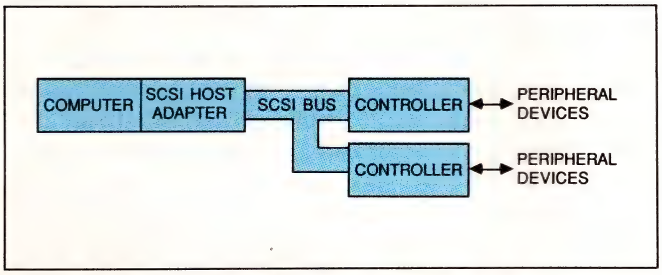


Fig 1—In this single-initiator, multiple-target system, *the initiator is the SCSI host adapter. It can communicate with any one of seven target devices, such as disk and tape drives.*

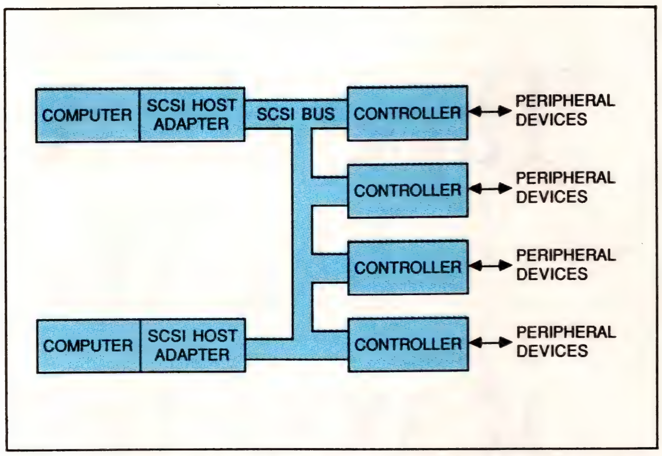


Fig 2—You can have more than one initiator in a system. *In this multiprocessor system, each processor has its own host adapter; both processors can use all the resources of the target devices. However, only two devices (one initiator and one target) can communicate at any one time.*

The primary difference is the size of the storage blocks. Disk drives typically perform I/O transfers in 512-byte blocks. In general, tape drives use much larger blocks. The QIC-100 (quarter-inch cartridge) format, for example, allocates data in 8k-byte blocks, which means that the smallest file on the tape occupies 8k bytes of storage space, even if its significant length is only a few bytes.

The tape's large data blocks mean that when you back up many small files on tape, they consume much more space than the sum of their actual lengths. You can improve the efficiency of storing many small files by creating a memory buffer that is the same size as a tape block; you fill the buffer with small files from the disk, and then write the buffer to tape as a single block.

The buffering technique introduces its own problems however. First you must modify the software drivers for the disk—standard SCSI disk drivers don't provide a buffering function. Second you have to read the entire block from tape in order to get any one of the files in the block, and if the files you want are not all in the same block, it takes even longer to get them. Thus, there's a tradeoff between speed of recovery and efficiency of storage.

Verification checks format

All data-storage devices are subject to read/write errors that arise from media defects, dust, electromagnetic fields, and other influences. Because of their high recording densities, today's tape cartridges are partic-

ularly vulnerable to loss of data integrity. Consequently their drives must provide some means of detecting and correcting errors. In a drive that has an embedded controller, the error-detection and -correction scheme is an integral part of the drive electronics. If that scheme is properly implemented, the hardware catches (and fixes) most errors on the fly without any need to report them to the host.

To check data reliability, tape drives generally have the means to verify the media format and the data areas. This verification process occurs just after formatting; the drive reads back the entire tape and checks the data-frame structure to verify that the tape is correctly formatted.

QIC-100 machines record data on 24 tracks in a serpentine pattern. The controller divides each track into 206 blocks **(Fig 3.)** Each block contains three 4k-byte frames, of which two hold user data and the third holds redundant data (computed during the write) for error-correction purposes. The first block of three frames on the tape constitutes the manufacturer's block and contains the bad-frame table. The next three frames constitute the use log, which identifies alternate frames and holds cartridge information, such as the date of manufacture and the number of times the cartridge has been inserted. The controller also reserves two blocks as alternates; thus 202 blocks, less bad blocks, are available for user data.

While it is verifying, the controller maintains reliability by updating the bad-frame table in the manufacturer's block with the IDs of any frames that do not format properly. If a block contains any bad frames, the controller does not map that block into the Logical Block Address space **(Fig 4)**, so the drive never writes

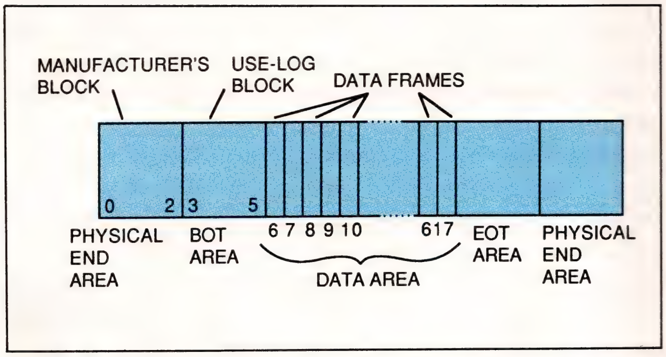


Fig 3—Each track of a QIC-100 tape has 618 data frames, *which are organized into 206 blocks. Two blocks hold historical data about the cartridge and the bad-frame list; two blocks are reserved as alternates. The remaining 202, less bad blocks, are available for user data.*

PHYSICAL BLOCK #	0	1	2	3	4	5	6	7	8	9
STATUS G = GOOD B = BAD	G	G	B	G	G	G	G	B	G	G
SCSI LOGICAL ADDRESS	0	1		2	3	4	5		6	7

Fig 4—The logical-addressing function isolates bad blocks. *This figure shows how the controller might assign logical block numbers, skipping over blocks that are known to be defective.*

data into a block that has a known bad frame. To ensure that the test is realistic, the controller reduces the gain while performing the verification; the reduced gain ensures that marginal bit cells on the tape produce errors and cause the relevant frames to be listed as bad.

The verification process is highly dependable, but it takes time. Formatting and verifying one of 3M's 205-ft DC 2000 ¼-in. cartridges, for example, takes about 32 minutes, of which about half entails verifying the cartridge and writing the bad-frame table. If the system is in such great use that this amount of time is inconvenient, most media vendors offer preformatted tapes.

Error detection relies on a CRC algorithm

Format verification ensures that you start out with good media and that the controller will skip over blocks that are known to be defective. However, transient errors may later prevent a proper write operation, and environmental conditions may damage the tape after you've recorded on it. To prevent loss of data from these causes, you need on-the-fly error-detection and -correction features.

The QIC-100's error-detection scheme relies on a 40-bit CRC (Cyclic Redundancy Check) code that the controller computes during a write operation and stores in the last five bytes of each block. Most disk drives depend on a 16-bit CRC, which is adequate for their smaller block size. The 8k-byte block size of the QIC-100 format requires a CRC at least 32 bits long for adequate error detection; the additional 8 bits of the QIC-100 CRC improve error detection and lower the possibility of miscorrections. During a read operation, the controller computes a new CRC code as it reads the block, and then compares the computed CRC code with the one stored on the tape during the write operation. Any discrepancy between the two codes indicates that

You can make a tape drive appear to the system like a disk drive, if you make the differences between the storage formats transparent to that system.

an error exists. By analyzing the CRC values, the controller can immediately correct many types of errors.

Data redundancy improves error correction

The CRC code cannot correct some types of error conditions, such as bursts of multiple-bit errors in contiguous bytes, or complete dropouts. For such errors, the QIC-100 standard requires an error-correction scheme that provides 50% data redundancy. This does not mean that 50% of the data is duplicated in its original form—such a scheme does not allow correction of errors in the unduplicated 50%. Rather it means that for each block, additional space equal to half the block size is allocated to error-correction data.

When you write a 3-frame block of data to the tape, the controller computes the exclusive OR of byte n of frame 1 and byte n of frame 2, and then stores the result in byte n of frame 3 (**Fig 5**). When you read the block, you can reconstruct unreadable bytes in frame 2 by computing the exclusive OR of the corresponding bytes in frame 1 (user data) and frame 3 (redundancy data). If the unreadable bytes are in frame 1, you reconstruct them by exclusive-ORing the corresponding bytes in frames 2 and 3.

The formatting and verifying processes, together with the on-the-fly error-detection and -correction scheme, yield highly reliable recorded data. An additional benefit of the error-correction scheme, as established by the QIC-100 standard and as tested by 3M, is that it helps to ensure interchangeability among QIC-100 cartridge drives.

Understanding the error-reporting features built into SCSI cartridge drives gives you some insight into how the I/O operations work. Error reporting, which isn't usually available on disk drives, lets you monitor exactly how well a tape drive is doing its job and, by revealing trends, provides a sense of any problems that may be gradually developing. It doesn't make any difference how many errors occur; what's important is the number of errors that go uncorrected.

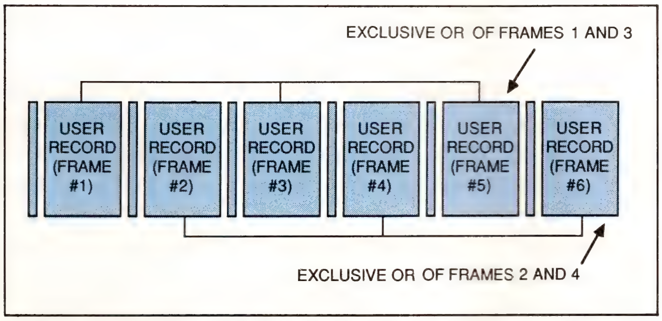


Fig 5—Redundant data lets you reconstruct damaged frames. *On this QIC-100 tape, which has an interleave of 2, block 1 contains user-data frames 1 and 3; each byte of frame 5 contains the exclusive OR of the corresponding bytes of frames 1 and 3, and allows you to reconstruct damaged bytes in those frames.*

Although error correction helps to ensure that data is correctly retrieved, even redundant data can sometimes be corrupted after it has been successfully written. The most frustrating thing in the world is to have important data on the medium and not be able to read it. For maximum reliability, therefore, cartridge drives provide a procedure that can recover from errors that occur after the initial write. This procedure is called the "heroic retry."

Keep the tape moving

Most tape drives offer normal retry procedures that simply read a block, perform error correction if an error is detected, and, if the error is uncorrectable, back up to the beginning of the block and try again. Occasionally, the error is simply that the drive cannot locate the block into which it wants to write data because it can't read the ID correctly. In this case, the heroic retry lets the drive increase the read gain by as much as 4 dB, and then repeat the operation.

The heroic retry can be used by a read operation also. If a normal read operation fails to read the data, the heroic retry attempts the same operation at increasing gain levels to the maximum of 4 dB above normal. The procedure can also move the heads over a range of 14 steps (0.002 in. each) both above and below the normal center-of-track position. The heroic retry serves to ensure that data recorded on one drive can be read by another, compatible drive. Under all common conditions of interchange, the heroic retry compensates for any differences between the two drives.

Measuring the efficiency of any tape-drive implementation is fairly simple: Watch the tape during backup operations; if the tape moves at a constant rate, the system is as efficient as it can be. But if the tape frequently stops and restarts, then something is out of balance. Most frequently it's data underrun (ie, the system isn't sending data at the rate necessary to keep the tape streaming, and so the drive must stop and wait for data). Whenever the tape stops because of data underrun, the drive must reposition the tape to the correct block and, because this process can take as much as two seconds, efficiency is seriously compromised.

Data-cartridge tape drives store data in 8k-byte blocks. Therefore, backing up many small files may occupy more tape space than you expect.

TABLE 1—EFFECTS OF INTERLEAVE FACTOR ON USABLE FRAMES

INTERLEAVE FACTOR	NO OF THREADS	BLOCKS/THREAD/ TRACK	USABLE FRAMES
2	2	102	612
3	3	68	612
4	4	51	612
5	5	40	600
6	6	34	612
7	7	29	609

The data rate required to keep a drive streaming varies with the interleave used; interleaving refers to the mapping of logical frames onto physical frames in such a manner that two consecutive logical frames are separated by one or more physical frames. The QIC-100 format permits interleave factors **(Table 1)** ranging from two (which maps logically consecutive frames onto every second physical frame) through seven (which maps logically consecutive frames onto every seventh physical frame).

You can also implement an interleave factor of one as an interleave of two, overlapped. In this situation, logically associated frames are separated by one physical frame, but the blocks are overlapped instead of consecutive. This technique prevents a single defect from corrupting an entire block.

Increasing the interleave factor gives the drive more time to receive data from the host before it has to write data to the tape. Since you can adjust the interleave factor, you can precisely match the system data rate to the tape data rate, thereby eliminating time-consuming stop-start operations. For example, a SCSI tape drive with an interleave of 1 requires that the system supply data at 42.2k bytes/sec to keep the tape streaming. If the system can't supply data that fast, you can increase the interleave; an interleave of 2 reduces the necessary system data-transfer rate to 21.1k bytes/sec; an interleave of 7 reduces it to only 6k bytes/sec. To correct an inefficient implementation, therefore, consider the possibility of increasing the tape interleave factor first.

Improve access time

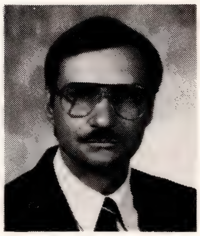
The access time of tape storage is notoriously slow, especially in microcomputer environments. In an MS-DOS system, for example, the Copy command frequently requires a great deal of tape movement. In 3M's MCD40 drive, this movement slows down access because the tape drive can take as much as 250 msec to reposition the tape; even worse, to locate a file, the drive has to look up the address in the directory, which is at the start of the tape—and a full end-to-end rewind takes 27 seconds.

There are several possible solutions to this problem. One requires that you take advantage of some spare storage space. The QIC-100 format provides 128 uncommitted bytes at the end of each data block on the tape. You might use these bytes to create a rolling directory, which obviates the need to do a complete rewind in order to consult the master directory. Another solution, and one that improves performance even more, is to keep an updated directory in the system memory.

Another way of speeding up tape-to-disk or disk-to-tape operations is to overlap the operations of the devices. The intelligence in SCSI peripherals allows the tape to read (or write) a block of data at the same time that the disk drive is seeking the next location at which to perform a write (or read).

Ultimately, incorporating into your system a SCSI tape drive that uses the random-access CCS isn't much more difficult than incorporating a SCSI disk drive. The factors that you have to consider are the potential of each type of peripheral and the means of tweaking system performance, rather than fundamental system-design problems. The CCS works well in a wide variety of system designs. And as more and more system integrators gain this understanding, easy and standard methods should appear for obtaining reliable and predictable performance from a mixture of all types of random-access peripherals. **EDN**

Author's biography



Tony Kozlowski is a senior product-development engineer at 3M Company (St Paul, MN), where his responsibilities include the design and development of the SCSI controller for the 3M MCD-40 Cartridge Tape Drive System. He holds a BSEE degree from Marquette University and is a member of the American National Standard Committee (ANSC) X3T9.2. In his free time, he enjoys tennis, photography, and gardening.

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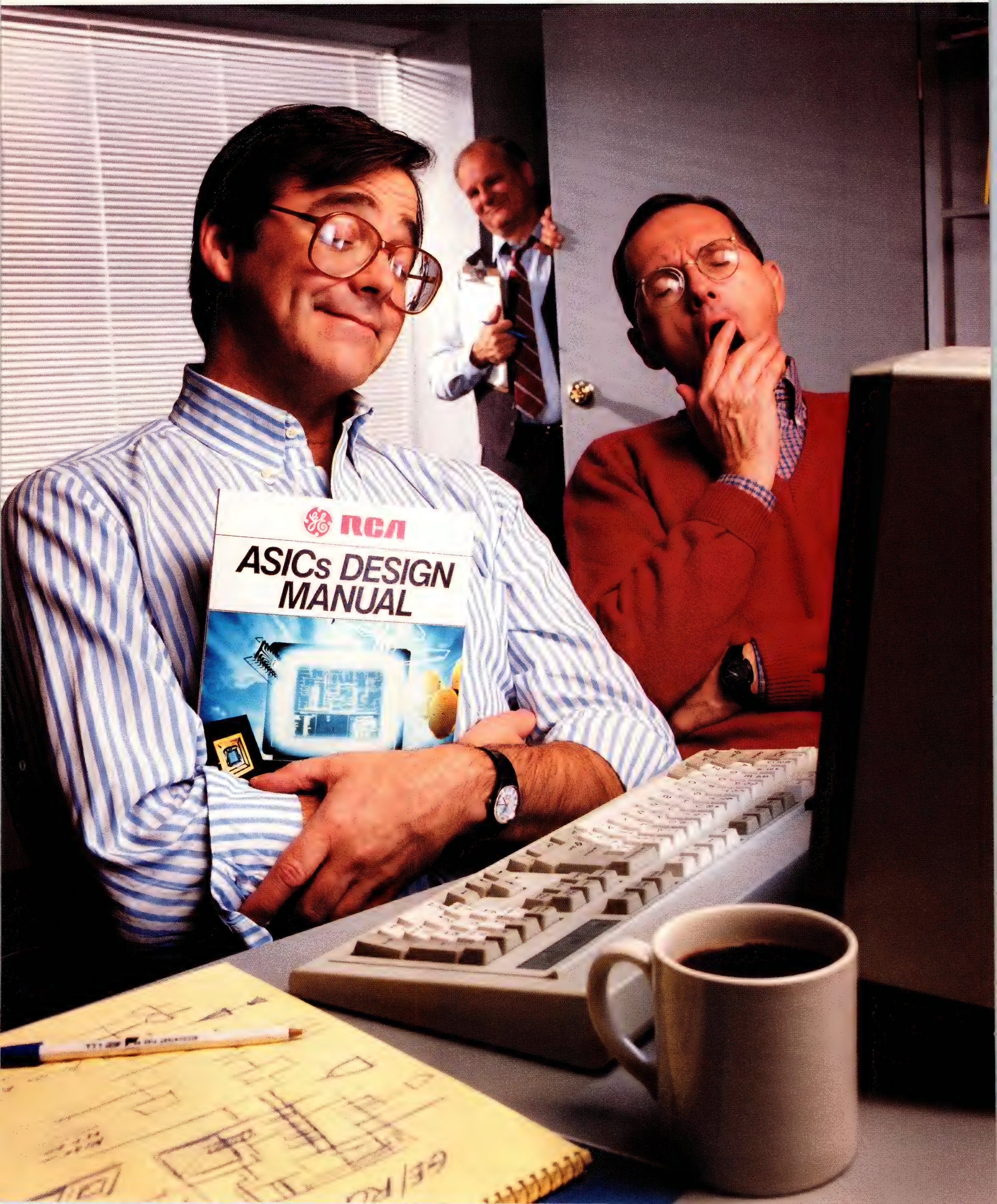

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New ±5V standard unshackles analog-IC designers

Since the late 1960s, ±15V dc supplies have been standard for analog ICs. Today, however, such supply voltages force unreasonable constraints on packing density and performance. Lower supply voltages yield significant improvements in integration and performance.

John Shier and Jerry Thimsen, *VTC Inc*

The scaling which digital-IC designers have applied so brilliantly to shrinking and speeding up their ICs has not been available to the analog engineer. Because such downscaling inevitably requires a lower supply voltage, the tyranny of ±15V suppplies (see **box,** "The origin of the ±15V standard") has sharply limited the development of analog LSI and analog ASICs. IC designers can pack only a very few functions onto a reasonably sized die. Until quite recently, analog-ASIC design tools, such as cell libraries, were nonexistent. And, those tools that have appeared since then don't use ±15V supplies.

A new standard appears

Although the old ±15V standard won't be instantly dethroned, a place does exist for a new ±5V standard. This new standard has decisive advantages for some applications—applications that will be a growing fraction of all future analog applications.

Among the beneficiaries of scaling, the first is the high-frequency engineer. Op amps, for example, have been extremely popular over the years as universal gain blocks. They have not been useful, however, at frequencies higher than 1 to 2 MHz, because of their inherent speed limitations. Instead, the high-frequency engineer has had to design with discrete components. Moreover, it is much harder to achieve high accuracy with open-loop, discrete designs than it is with op amps using negative feedback. The frequency limits of recently developed, scaled video op amps are an order of magnitude higher than unscaled op amps—10 to 20 MHz.

For high-frequency applications, an ultrafast ±15V amplifier is unusable because of excessive power consumption. Even though such a device can drive its load with ±10V signal swings, given the low load impedances (such as transmission lines) characteristic of high-frequency electronics, such large signal swings will burn too much power. For example, it would require at least 200-mA driver currents to drive a 50Ω load (such as a coaxial cable) to ±10V amplitude. At this drive level, the driver IC would dissipate 6W.

Another beneficiary of scaling is the system designer inherently constrained by low supply voltages. The high-frequency systems where ±5V analog ICs are most attractive are also those most likely to use ECL for the digital part of the system. With the 12V supplies common for peripherals, designers can readily generate a 10V analog supply with an inexpensive monolithic regulator that works well with ±5V parts.

Many of today's analog ICs actually will operate with reduced supply voltages (such as ±5V), but they were not designed for low-voltage operation and often work

By choosing a ±15V supply, the IC designer gives up several other benefits such as small transistor size, low parasitic capacitance, and rapid switching.

poorly. To better understand the limitations that power supplies impose on analog ICs, consider the following. Due to power supply tolerances, analog-IC designers must allow for nominal ±15V supplies actually running at ±16.5V (±10% tolerance). Thus, an analog IC's transistors must withstand at least 33V in the off state. Such a breakdown voltage mandates a spacing of at least several microns between the collector-base junction and the underlying collector-buried layer. All other junctions (especially relevant for the isolation junction) must also have very wide spacings. These requirements result in a *big* transistor. By choosing to maintain ±15V supplies, the IC designer inherently trades away several other benefits such as small transistor size, low parasitic capacitance, and rapid switching.

The poor frequency response and large size of the lateral pnp transistor has made it a limiting element in many conventional analog-IC designs. When IC designers attempt scaled, analog ICs, the transistor's limitations go from serious to disastrous. Consequently, some IC designers use more complex processes such as vertical pnp transistors. In one case, the fundamental speed (f_T) of the vertical pnp transistor is 1.5 GHz vs the 5 MHz of the conventional lateral pnp transistor.

For comparison purposes, **Fig 1** shows a scale drawing of a conventional 15V transistor and a scaled 5V transistor. **Table 1** describes the transistors' properties. The differences are quite dramatic. The low-voltage transistor's packing density, fundamental speed, and parasitic capacitance are all more than an order of magnitude better than those of the high-voltage transistor.

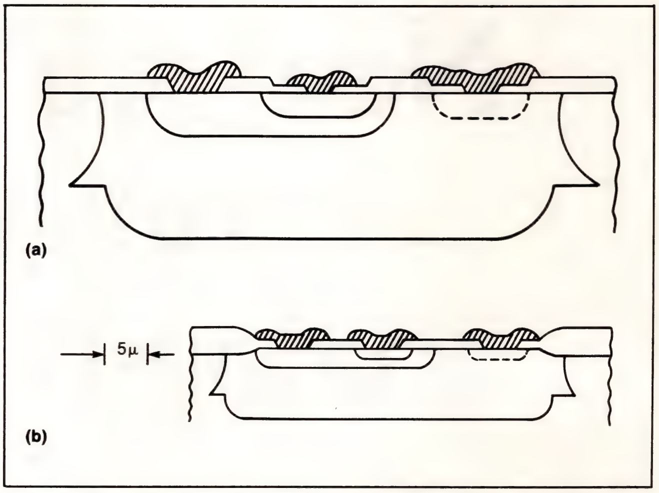

***Fig 1—The need for high breakdown voltages** to withstand ±15V dc supplies has meant that analog ICs need large structures **(a)**. The smaller structure **(b)** shows the shrinkage possible with ±5V supplies. The smaller structure is not a direct scaling of the large one, but includes refinements such as partial oxide isolation.*

TABLE 1—COMPARISON OF TRANSISTORS

PROPERTY	±15V	±5V
DEVICE AREA (SQ MICRONS)	6138	207
UNITY-GAIN FREQUENCY (f_T)	300 MHz	6 GHz
COLLECTOR-SUBSTRATE CAPACITANCE	1.2 pF	0.1 pF
BREAKDOWN VOLTAGE (BV_{CEO})	35V	12V

Signal swing is affected

Lower supply voltages can affect many properties of analog ICs. For example, conventional analog ICs allow signal swings to ±10V. These swings are acceptable as long as they exceed such errors as noise, offsets, and crosstalk (pickup) by an acceptable margin. Chips operating with lower supply voltages will have correspondingly lower signal swings. Although, in some instances, the large swings will still prove necessary to maintain adequate S/N ratio and accuracy, using today's high-quality analog ICs is overkill most of the time. Many designs can tolerate substantially smaller swings and still maintain adequate error margins.

Power dissipation is a key factor in applications. To understand how downscaling supply voltages affects dissipation, consider two otherwise-identical ICs dissipating 100 mW, but with one operating from ±15V and one from ±5V. The high-voltage chip can use only 3.3 mA for all of its circuits, whereas the low-voltage chip can consume 10 mA. If a resistor in the high-voltage chip carries 0.1 mA, in the low-voltage chip, it can carry 0.3 mA for the same chip-wide power dissipation. Moreover, its voltage drop will typically need to be about three times smaller because of the smaller signal swing. Thus, the low-voltage IC's resistor will have a ninefold smaller value, and the associated nodal RC time constant will be ninefold smaller (other things being equal).

Other things are not equal, however. By shrinking the transistor size, you achieve a three to fivefold lower node capacitance. Thus, scaling at constant power yields internal RC time constants for an analog, low-voltage IC that are 25 to 50 times smaller than those of a high-voltage IC.

The same parameters also affect slew rates. The available current in a low-voltage IC, *I*, will be three times higher, and the internal node capacitance three to five times smaller, than in a high-voltage IC. Because

[dV/dt]=[I/C], low-voltage ICs exhibit a dramatic increase in slew rate.

Of course, you can play this scaling game several ways. By keeping the supply current the same, you achieve a three to fivefold improvement in speed with a threefold drop in power. When going for equal performance, you can cut power comsumption by 10 to 15 times.

Moreover, RC time constants do not dominate all IC speed problems. The basic frequency response (f_T) of an IC's transistors may also be important, especially if parasitic resistive and capacitive elements are small. Here too, there is good news; shrinking the size of transistor elements yields a several-fold improvement in basic active-device speed **(Fig 2).**

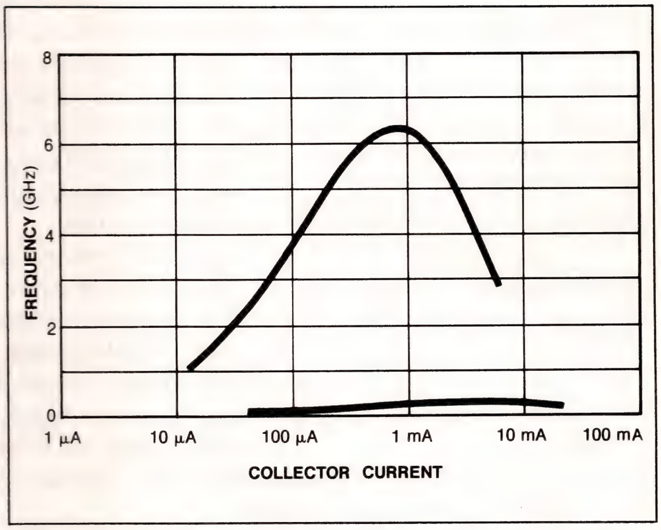

Fig 2—Speed also improves when transistors shrink. *The unity gain frequencies (f_T) for the transistors of* ***Fig 1*** *show a roughly 15-fold advantage for the scaled device.*

What supply voltages are best?

Although other possibilities exist for a new analog-voltage standard, ±5V is a good practical choice for

The origin of the ±15V standard

The old, and still existing, standard for analog supply voltages is ±15V. If you look into the catalogs of such analog vendors as National, Linear Technology, Precision Monolithics, Analog Devices, and Burr-Brown, you will see device after device specified for ±15V dc supplies. This convention is nearly universal for op amps, and almost universal for instrumentation amps, comparators, ADCs, and DACs.

The standard ±15V analog voltage dates back to the early 1960s, when the transistor was still a rather new device. One of the technological fads of the 1950s and 60s was the analog computer, and the operational amplifier was a key element in such computers. The earliest models employed tubes and, consequently, used very large supply voltages—like ±100V.

Given this demand, op-amp module vendors came into being to supply the hardware. Analog Devices and Philbrick Research (now part of Teledyne) were two of the leading producers.

Op-amp designers embraced the new transistor with enthusiasm. It solved many of the weight, power, and dc-drift problems that plagued vacuum tubes. But, transistors could not operate with the very high voltages of tubes because of the limitations of the available solid-state technology. A smaller supply voltage of ±15V came to be a standard for these modular op amps.

Analog computers died during the 1960s because of the rapid progress in digital electronics. But, in the meantime, the existing op amps (made as potted modules) were proving useful in various instrumentation applications. Thus, the pioneering IC designers of the 60s naturally turned their attention to integrating an op amp on a single substrate.

The first product appeared in the mid-60s from Fairchild. Bob Widlar designed it, and it was called the μA709. This op amp was followed shortly by the μA741, which became an industry standard and is still finding use in designs even today (truly remarkable longevity for an IC). In developing these pioneer analog ICs, the designers used a deep-junction, thick-epi process that provided a breakdown voltage of BV_{CEO}>35V.

The large geometries and deep junctions used in analog ICs were not very exceptional in the 60s, because even digital ICs used coarse geometries and had high breakdown voltages. The technological limitations of the day were such that a 16-*bit* RAM was considered a very big deal.

The poor frequency response and large size of the lateral pnp transistor has made it a limiting element in many conventional analog IC designs.

system reasons. A +5V supply is standard for both TTL and CMOS, and −5.2V is the ECL standard. In other words, in some systems ±5V dc supplies are already available. In addition, there are already indications of a modest move toward ±5V. Several conventional analog-IC vendors now put ±5V characterization data on their data sheets. And a small but significant number of new ±5V chip offerings are appearing.

The opportunities that downscaling will create for greater functional complexity are immense. For example, a widely used 12-bit ±15V A/D converter occupies a 200×200-mil die and uses perhaps 500 active devices. By comparison, the same die size (200×200) is typical of 8-bit flash converters, which employ modern, highly scaled bipolar processes and operate with ±5V or −5.2V supplies. The flash converter can squeeze in around 5000 to 7000 active devices.

Fig 3 shows a developmental 12-bit, ±5V ADC that integrates a DAC, successive-approximation register (SAR), control logic, and voltage reference on a 17,000-mil^2 die. Comparable devices using ±15V supplies occupy 40,000 mil^2. The prototype device's conversion speed improves from the 10 to 25 μsec typical of high-voltage ADCs to less than 2.5 μsec.

In another example, using a proprietary A/D ASIC reduced a 3½×9-in. pc board with 17 ICs to a single 28-pin, 5V chip, which performed with much less noise and jitter than the prototype. Only downscaled chips offer the analog world the opportunities to achieve the same kinds of size, cost, power, performance, and functional improvements that digital ICs have achieved.

A precision operational amplifier, the VA701, serves as an example of a ±5V analog design. It is comparable to the industry-standard OP-27/37 amplifier (**Table 2**).

TABLE 2—COMPARISON OF OP AMPS

PARAMETER	VA701	OP-27
SUPPLY VOLTAGE (V)	±5	±15
POWER CONSUMPTION (mW)	70	140
INPUT OFFSET VOLTAGE (μV)	25	25
INPUT BIAS CURRENT (nA)	40	60
OPEN-LOOP GAIN (V/mV)	6000	1800
SLEW RATE (V/μSEC)	10	1.7
GAIN-BANDWIDTH PRODUCT (MHz)	30	8
NOISE DENSITY @ 1 kHz (nV/√Hz)	3.0	3.0
USEFUL SIGNAL SWING (V)	±2.5	±10

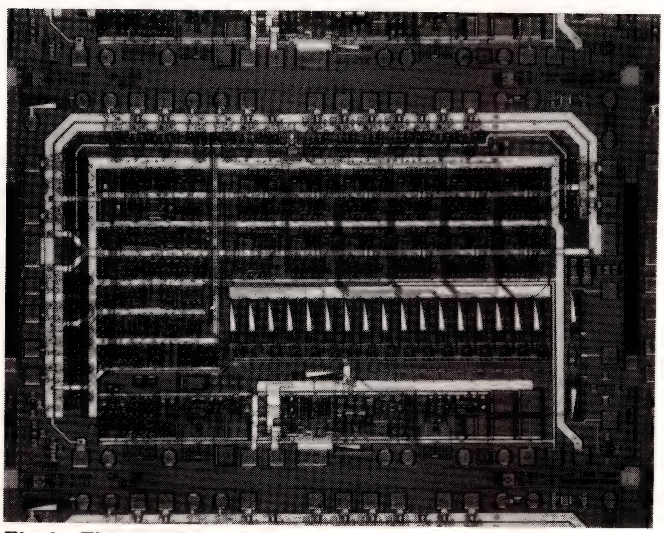

*Fig 3—**This developmental 12-bit, ±5V ADC** integrates a DAC, successive-approximation register, control logic, and voltage reference on a 17,000-mil^2 die. Comparable devices using ±15V supplies occupy 40,000 mil^2. The prototype device's conversion speed improves from the 10 to 25 μsec typical of high-voltage ADCs to less than 2.5 μsec.*

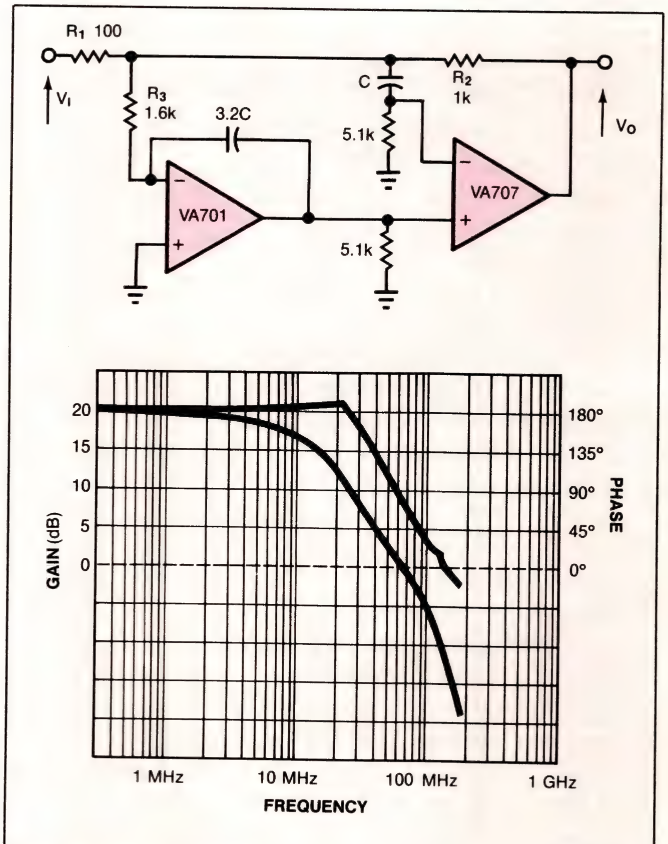

*Fig 4—**Op amps optimized for ±5V operation** yield a composite amplifier with a gain of 20 dB and a bandwidth of better than 30 MHz. They can replace open-loop video amplifiers designed with discrete components, and they offer advantages in linearity, size, and power dissipation.*

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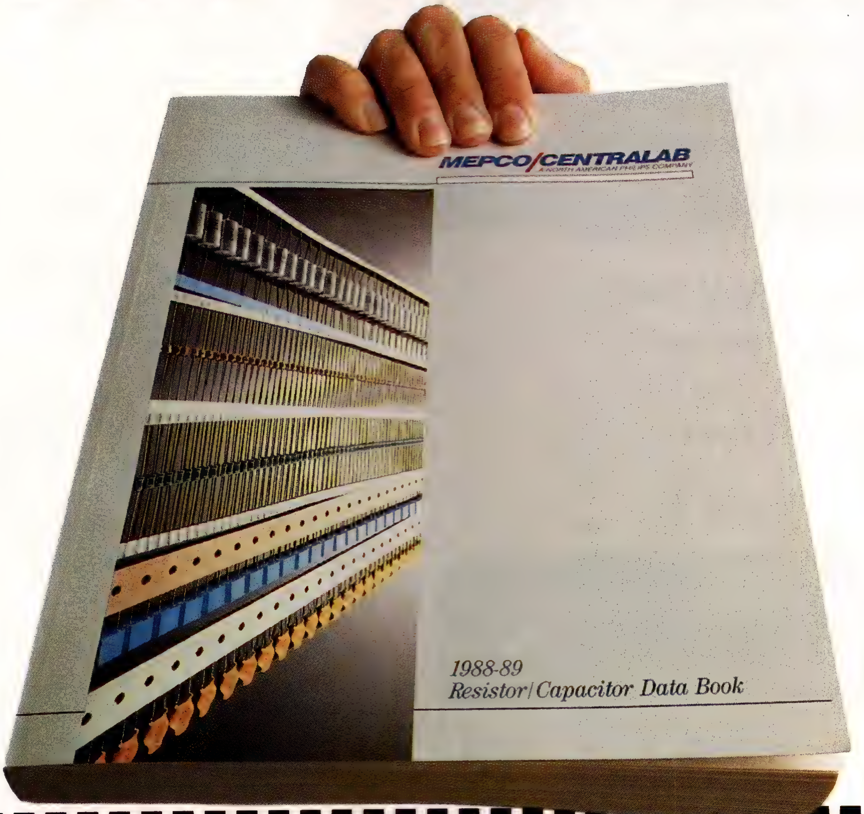

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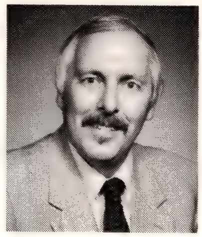
Scaling has improved performance and reduced power consumption just as expected. Note, however, that the input-offset voltage is the same for both chips. **Fig 4** shows how you can use the VA701 (high precision) and VA707 (high speed) op amps in a high-performance composite amplifier.

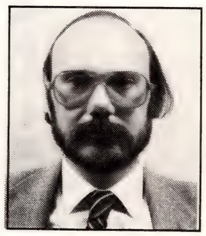
Package parasitics do not affect the operation of conventional analog components at their typically low operating frequency. Packaging headaches come with improved performance. The parasitic capacitance and inductance of DIPs can have very significant effects on signals in the 10- to 100-MHz region. However, the recent widespread adoption of PLCC and SOIC packages promises to help greatly. The parasitics of these packages are several-fold smaller.

As an illustration of how packaging affects performance, consider a fast comparator that proved twice as fast in a SOIC as in a DIP (the propagation delay) was roughly 1 nsec vs 2 nsec). Advanced, wideband, analog ICs often display their best speed in chip-and-wire hybrid ICs, where off-chip parasitics are radically less than those of conventional packages. **EDN**

Authors' biographies



John Shier is the strategic marketing manager for VTC (Bloomington, MN). John received a BS degree from the California Institute of Technology, and MS and PhD degrees from the University of Illinois, all of which were in physics. He has held IC processing and design positions at Signetics, AMD, Intersil, Sperry Univac, and CDC. In his spare time, he enjoys reading, sailing, and gardening.



Jerry Thimsen is the product line manager for linear signal processing products at VTC. He was previously component engineering manager at Magnetic Peripherals Inc and has held similar positions at Northern Telecom and Data 100. In his spare time, he enjoys whitewater canoeing, backpacking, photography, and reading.

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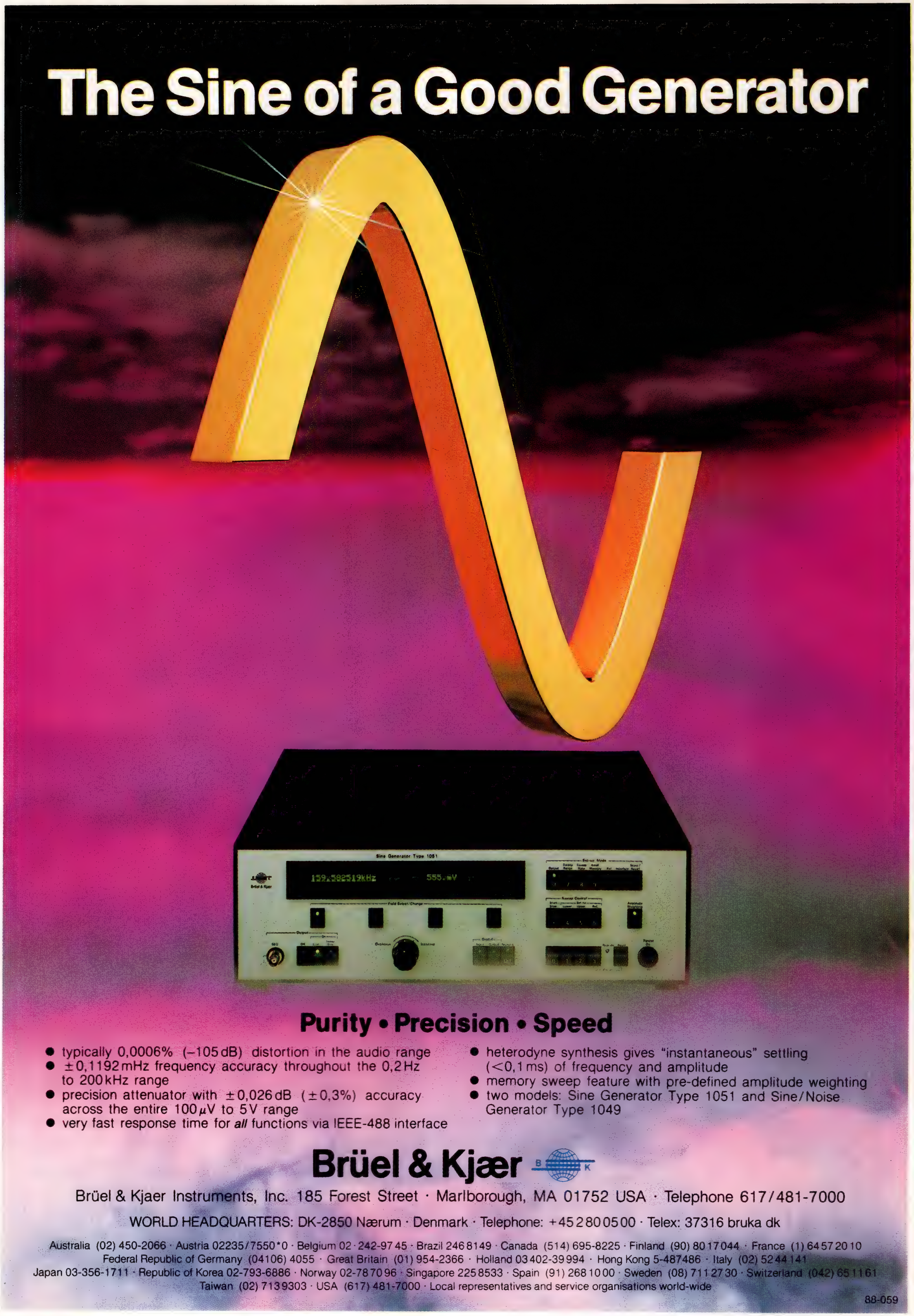
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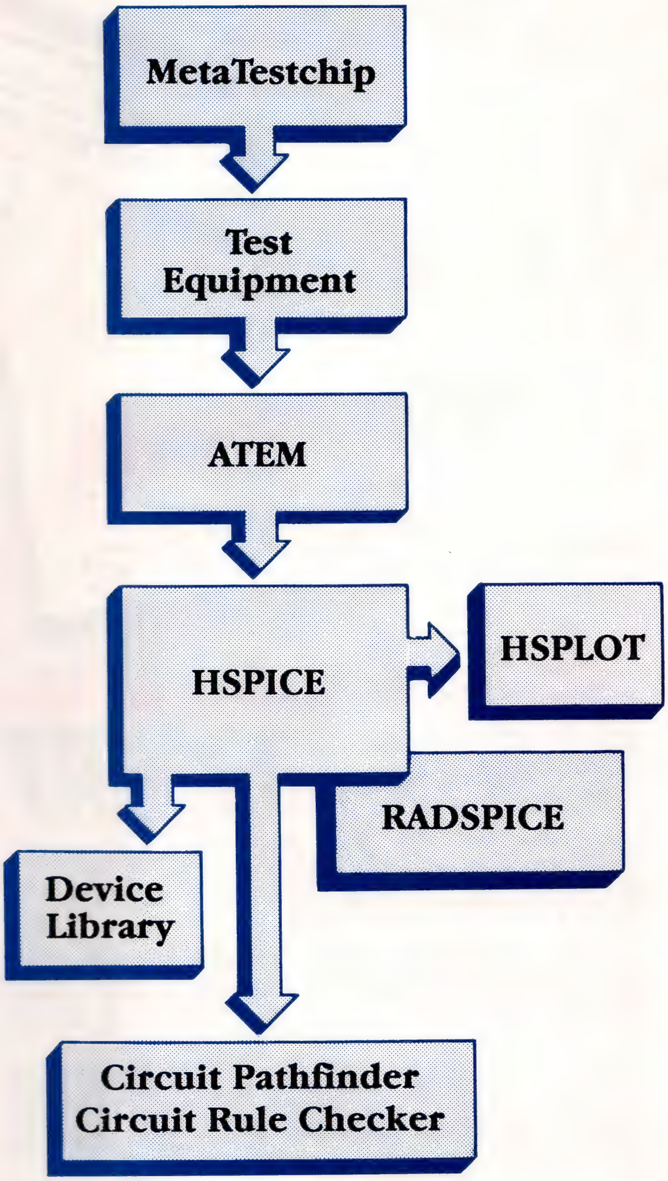

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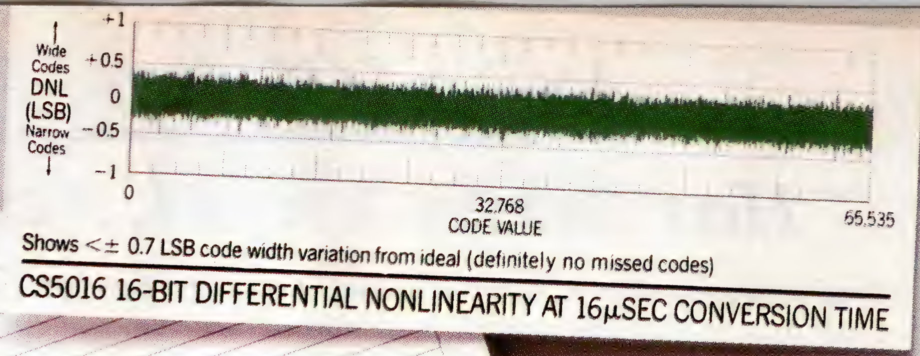

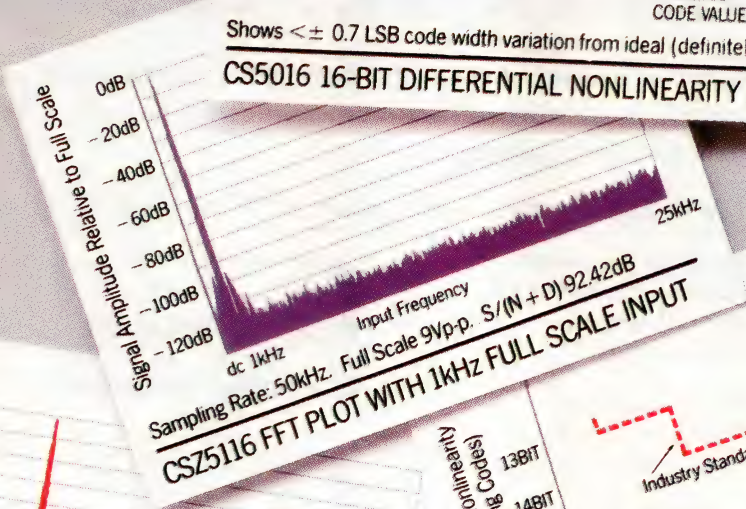

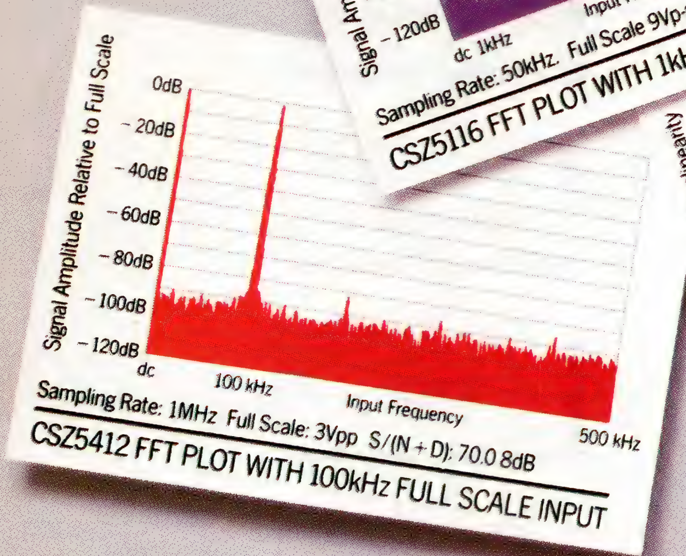

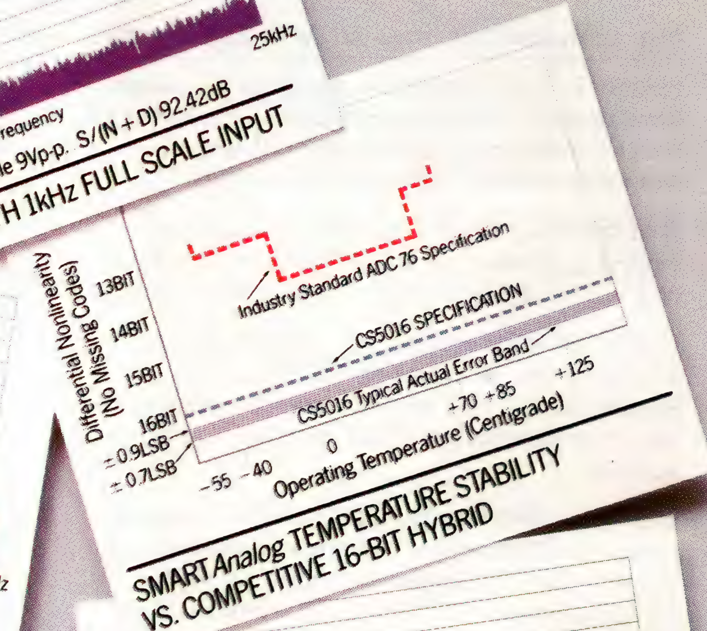

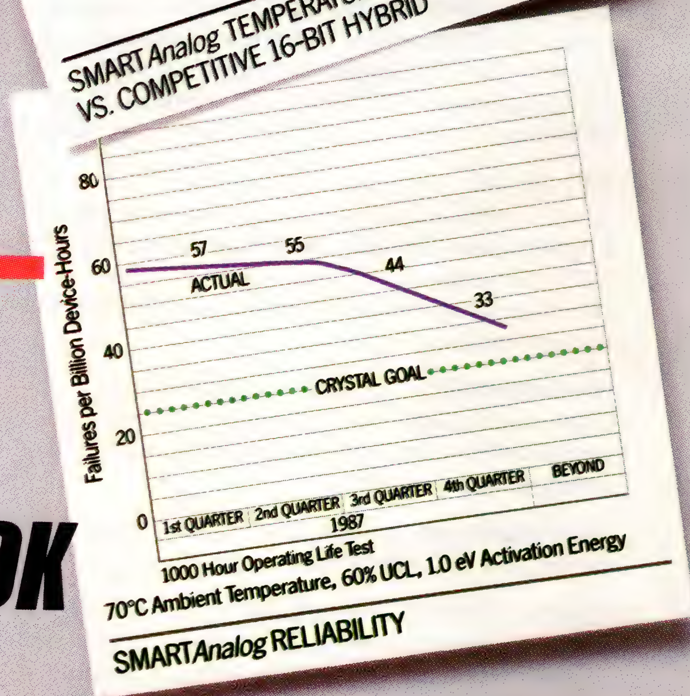

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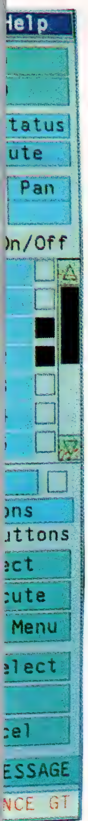

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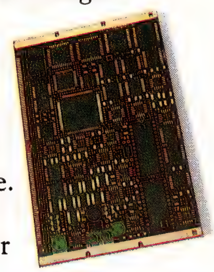

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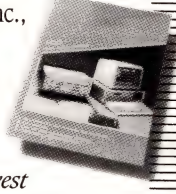

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OUTLOOK

Processing advances push GaAs ICs to higher VLSI levels

For most designers, digital GaAs ICs mean high-speed circuitry. But because of breakthroughs in fabrication, some of these ICs are now suitable for use in more complicated VLSI designs, creating new trade-off issues when selecting ICs.

Louis R Tomasetta, *Vitesse Semiconductor Corp*

Designers have long associated digital GaAs ICs with the slogan "speed at any price." However, developments both in GaAs IC manufacturing and in other technologies (most notably silicon ECL) have made the selection of ICs more complicated. The price now may involve not just trading dollars and cents for a certain frequency response. Other issues come into play, such as power consumption, circuit complexity, I/O compatibility, and packaging considerations—and digital GaAs products can successfully compete with silicon ECL on those points.

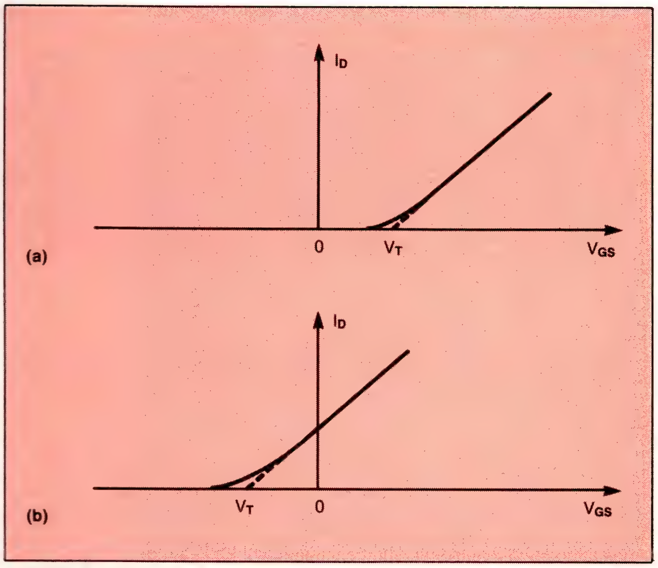


Fig 1—Because an n-channel enhancement-mode device (a) draws no drain current (I_D) when the gate-to-source voltage (V_{GS}) is 0, the device is normally off. In contrast, an n-channel depletion-mode device (b), which draws drain current when V_{GS} equals 0, is normally on.

D-mode vs E-mode FETs

Basically, digital GaAs circuits can use two types of transistors: the depletion-mode FET (D-mode FET) and the enhancement-mode FET (E-mode FET). The E-mode FET has a channel with less doping than the D-mode FET. Therefore, in order to turn on, any n-channel E-mode device needs a positive gate-to-source voltage that exceeds the threshold voltage. In contrast, a D-mode FET requires a negative gate-to-source voltage to turn the transistor off. Thus, D-mode FETs are normally on, and E-mode FETs are normally off (**Fig 1**).

Digital GaAs products can successfully compete with silicon ECL on the issues of power consumption, I/O compatibility, circuit complexity, and packaging.

The most popular approach in the US for fabricating digital GaAs FETs is the direct-implant technique (**Fig 2a.**) This procedure implants the channel, implants the source and drain (usually a higher dose than the channel), anneals the implants, and then deposits the contacts and the gate. The aligning of the gate to the source and drain is imprecise, however, because the gates are deposited after the annealing process. The channel length must span not only the gate length but the alignment tolerances needed to deposit the gate.

Logic design determines applications

Manufacturing processes define which logic types you can use in a given application. **Fig A** shows some of the more common logic configurations. The first implementation of a GaAs logic gate was the Buffered MESFET Logic (BFL) family **(Aa).** The family contains depletion-mode FETs only with threshold voltages ranging from −2.0 to −1.0V. In the BFL's 2-input NOR gate, the 2 diodes shift the output high and low levels to encompass the threshold of the next gate. A pull-up transistor acts as the load and that transistor's size affects the power dissipation and speed of the gate. The BFL gate performs well with high fan-outs but dissipates a lot of power per gate—2 to 5 mW. The BFL configuration is also relatively insensitive to processing and power-supply variations. It's the most popular design for commercial GaAs SSI and MSI digital ICs.

The FET logic (FETL) gate implementation (**Fig Ab**) eliminates the pull-up transistor so that the gate dissipates less power than the BFL configuration. The FETL gate also uses Schottky diodes as level-shifters. However, this implementation is more sensitive to fan-out loading and is slower than the BFL gate.

The capacitively enhanced logic (CEL) gate operates at a higher speed than the FET logic gate without paying a penalty in high power dissipation **(Fig Ac).** The CEL gate places a reverse-biased diode across the Schottky level-shifting diodes to act as a speed-up capacitor. The capacitor provides a direct path to the output during high-speed transitions. However, like the FETL gate, the CEL configuration is sensitive to fan-out loading because it lacks a pull-up transistor.

Since all of these families use only depletion-mode devices, their logic levels can be compati-

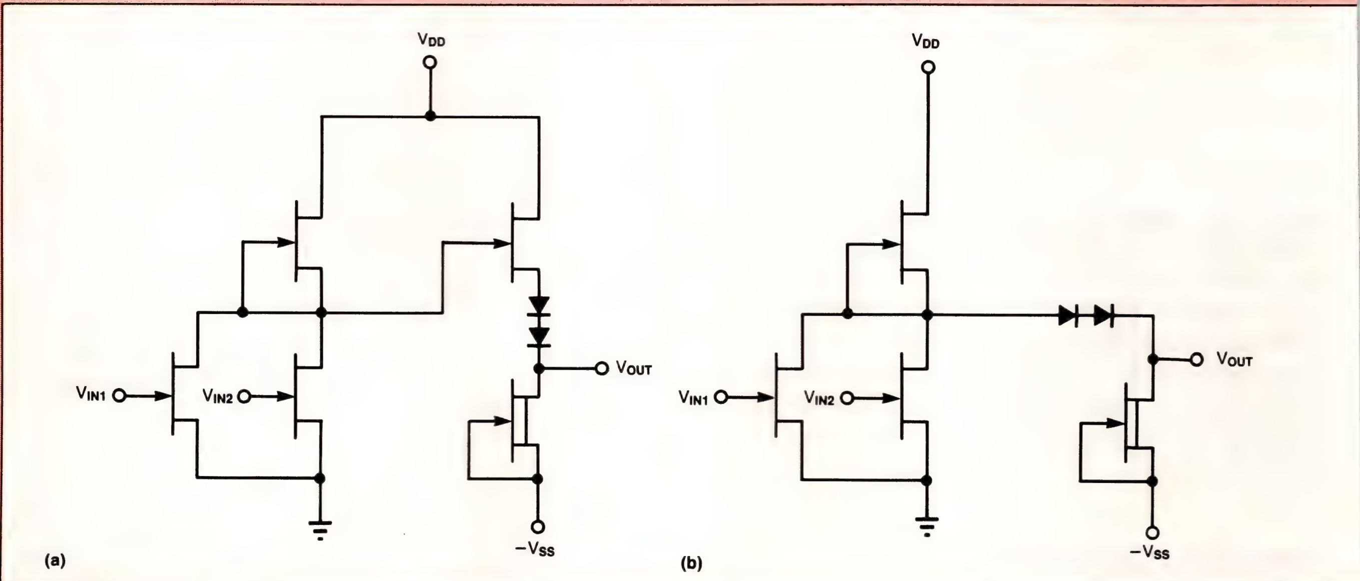


Fig A—Five 2-input NOR gate configurations*—the BFL* ***(a)****, the FETL* ***(b)****, the CEL* ***(c)****, the DCFL* ***(d)****, and the SCFL* ***(e)****, for GaAs logic circuits exhibit tradeoffs between speed, power, complexity, and manufacturability.*

This extra length creates a high resistance region in the channel.

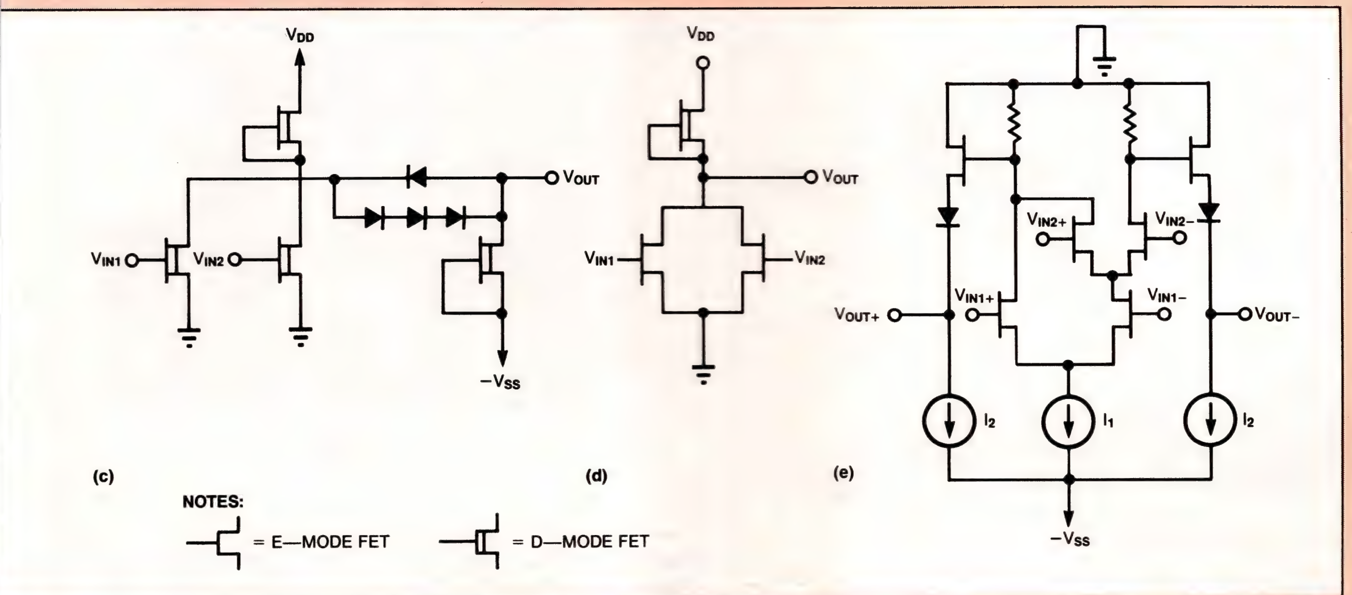
An approach used in the fabrication of silicon MOSFETs, known as the self-aligned gate, avoids this imprecision by depositing the gate metal as a mask for implanting the source and drain (**Fig 2b**). Each channel length is consequently equal to the gate length, so the source and drain are perfectly aligned to the gate. Furthermore, this approach reduces the channel resistance and the size of the FET.

ble. Thus, you can mix these families together on the same chip. For designs with low fan-out, you can use a CEL gate for high speed and low power dissipation, or you can use a BFL gate for driving high-capacitance loads.

Saving power

The availability of the self-aligning technique for GaAs processing technology allows you to design logic gates using E-mode and D-mode FETs efficiently. One of these designs uses the Direct-Coupled FET Logic (DCFL) configuration (**Fig Ad**). The design connects a D-mode FET, configured as a current source, to the drains of two E-mode FETs. This design eliminates the level-shifting diodes between logic stages. Consequently, the DCFL gate is smaller and dissipates less power than the depletion-mode logic families. The design is similar to that of enhancement- and depletion-mode NMOS circuitry with a lower power supply voltage (approximately 2V). The gate turns on when the gate voltage exceeds the gate-diode voltage, which is typically 0.8V.

In order to overcome some of the limitations of DCFL, some manufacturers use a Source-Coupled FET Logic (SCFL) configuration. A 2-input NOR gate with differential inputs is shown in **Fig Ae.** The families that use this configuration are similar in basic connections to the silicon ECL and CML (current-mode logic) families. The SCFL approach is less sensitive than the DCFL to processing variations since it only requires that two adjacent transistors have well-matched pinch-off voltages. It is also less sensitive to capacitive loading than DCFL. However, each gate draws more power and occupies more area than the DCFL family.



The fabrication process for digital GaAs ICs can use high resistance metals.

Manufacturers of silicon ICs have adopted the self-aligned gate technique as the norm, but GaAs IC makers couldn't use it until they identified gate metals that can withstand the annealing temperature, which is greater than 800°C. Gold, which is the lowest resistance metal, alloys with GaAs and becomes ohmic at temperatures approaching 400°C. Fortunately, digital ICs have small gate widths (the lengths remain standard), so their fabrication process can use metals with higher resistivity without the RC time constant (a product of the gate resistance and capacitance) becoming a dominant factor. Refractory metals like tungsten, tungsten silicide, and platinum are suitable for self-aligned gates.

Another obstacle for GaAs IC manufacturers involves the fact that, even with a refractory metal gate, you need a process that deposits the metal without letting any arsenic escape from the surface at the annealing temperature. If arsenic escapes, the surface contains excess gallium, which changes the electrical properties of the FET.

A variation of the self-aligning technique uses a dummy gate (usually SiO_2 or Si_3N_4) during the annealing process. The process replaces the dummy gate with a gold gate after annealing. Although this approach obviates both the metal and the arsenic problem and achieves a comparable device structure, it requires additional processing and lithography steps.

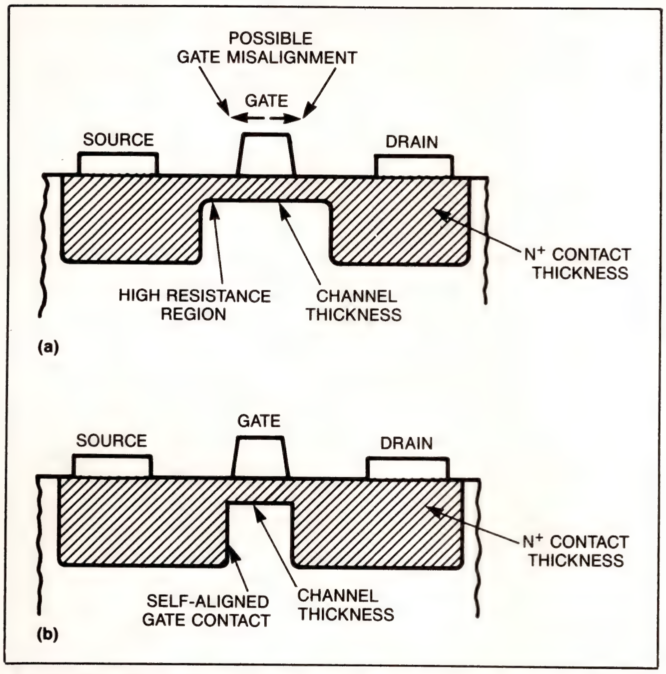


***Fig 2—The direct implant processing technique (a) produces high resistance regions in the channel.** The self-aligned gate approach **(b)** eliminates those regions, but the gate metal must withstand the annealing temperature.*

Process control defines logic

Various processing advances have created a number of different GaAs logic families (see **box,** "Logic design determines applications"). **Fig 3** shows a general comparison of the typical performance of various types of digital GaAs products with those of CMOS and silicon ECL chips. Obviously, the various technologies overlap: You could, for example, use a GaAs depletion-mode device for a 500-MHz circuit or you could use a 1-μm ECL IC. High-power 1-μm ECL technology can achieve flip-flop toggle rates of 1000 MHz with power

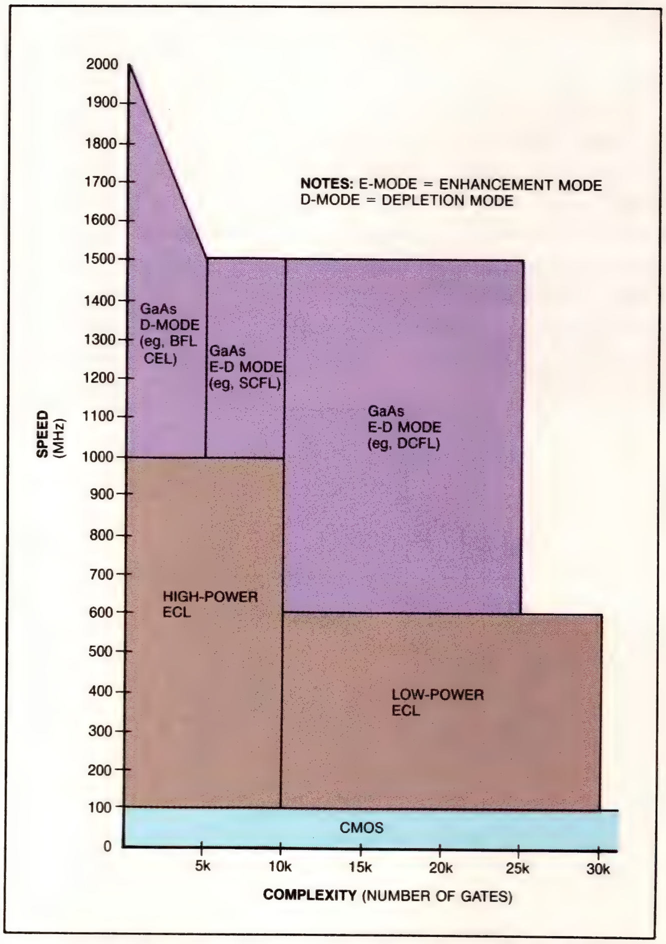


***Fig 3—In this approximate comparison, the performance levels for digital GaAs products** and other digital technologies overlap. The maximum power dissipation per package is reached at the point that allows the greatest complexity times the gate-power dissipation. For high-power ECL devices, the maximum power dissipation is 15W; for DCFL devices, it's 5W.*

TABLE 1—A COMPARISON OF FEATURES OF VARIOUS GaAs AND ECL LOGIC FAMILIES

	FLIP-FLOP TOGGLE RATE (MHz)	POWER/GATE (mW)	COMPLEXITY[1] (GATES)	THRESHOLD CONTROL REQUIRED[2] (mV)	MASK LEVELS
GaAs					
BFL	2000	2 TO 5	1000 TO 2000	100	9 TO 10
CEL	1800	1 TO 2	2500 TO 5000	100	9 TO 10
SCFL[3]	1500	0.5 TO 2	2500 TO 10,000	50	9 TO 10
DCFL	1500	0.2 TO 0.4	12,000 TO 25,000	15	9 TO 10
ECL					
HIGH POWER	1000	1.5 TO 2	7500 TO 10,000	NA	16 TO 20
LOW POWER	600	0.5 TO 1	15,000 TO 30,000	NA	16 TO 20

NOTES:
1. 5W LIMIT FOR GaAs; 15W LIMIT FOR ECL.
2. STANDARD DEVIATION OF E-MODE FETs FOR E-D LOGIC; OF D-MODE FETs FOR D-MODE LOGIC.
3. INCLUDES OTHER E-D (NON-DCFL) LOGIC.

dissipations of 1.5 to 2 mW for each gate. Assuming a power-dissipation limit for an ECL VLSI package of 15W, the complexity limit for ECL devices is 7500 to 10,000 gates. In applications that require that kind of complexity, ECL is 5 to 10 times faster than CMOS.

E-D devices run at 1500 MHz

Table 1 summarizes the features of the various GaAs logic families along with 1-μm ECL. By connecting enhancement- and depletion-mode (E-D) GaAs devices in a direct-coupled FET logic (DCFL) configuration, you can achieve flip-flop toggle rates of 1500 MHz while dissipating 0.2 to 0.4 mW per gate.

Power dissipation vs complexity

Other configurations for E-D GaAs devices, such as source-coupled FET logic (a variant of the ECL configuration), achieve flip-flop toggle rates as high as 1500 MHz, but they dissipate 0.5 to 2 mW per gate. Depletion-mode-only configurations, such as buffer FET logic (BFL) and capacitively enhanced logic (CEL), offer higher toggle speeds at the expense of high power dissipation.

Since the thermal conductivity of GaAs is one-third that of silicon, a GaAs package's power-dissipation limit of 5W maintains a temperature rise in the substrate comparable to a 15W ECL package. Under this constraint, a complexity limit for DCFL devices can be 12,000 to 25,000 gates. The high power dissipation of the BFL and CEL families limits these devices to SSI and MSI complexities (less than 2000 gates).

TABLE 2—COMPARISON OF CIRCUIT RESULTS FOR THREE GaAs LOGIC FAMILIES

	DCFL	BLF	CEL
NOR GATE SWITCHING POINT	0.32V	−0.16V	−0.10V
RING OSCILLATOR WITH F_1/F_2 = 2/2 MINIMUM GATE DELAY	44 pSEC	47 pSEC	39 pSEC
ASSOCIATED POWER DISSIPATION	0.55 mW	3.4 mW	2.8 mW
POWER-DELAY PRODUCTS	24 fJ	160 fJ	109 fJ
DIVIDE-BY-2 CIRCUITS MAXIMUM INPUT FREQUENCY	3.1 GHz	2.7 GHz	3.8 GHz
ASSOCIATED POWER DISSIPATION	3.4 mW	18 mW	25 mW

(SOURCE: ITT CORP)

In a hands-on comparison of the BFL, CEL, and DCFL families, an ITT lab team fabricated ring oscillators, flip-flops, and shift registers on the same GaAs substrate and compared their relative performances. A self-aligned gate process produced E-mode and D-mode FETs with pinch-off voltages of 0.1V and -0.5V, respectively. The gate length was one micron. **Table 2** summarizes results for the three logic families. The report concluded that DCFL is the preferred logic design if processing tolerances are controllable.

The greatest opportunities for digital GaAs ICs, therefore, lie in areas requiring both high speed and

high complexity. To achieve VLSI integration (greater than 10,000 gates), with a chip power dissipation of 5W, only the DCFL configuration is viable. The major requirement is process control when fabricating these devices. For example, for a DCFL gate to work properly, the pinch-off voltage of the E-mode FET must remain within a 0.15 to 0.4V range.

Moreover, the threshold voltage of the E-mode FET determines the speed and yield of the wafer. The transconductance (g_m) of the FET improves with a lower threshold. If the spread of threshold voltages is too large, some E-mode FETs may have thresholds less than 0V and won't turn off. A higher threshold will increase yields, but performance suffers. In addition, a tight spread on the threshold voltage of the E-mode FETs insures a tight spread on the current drain for each gate.

The improvements of 1-μm ECL devices, however, have left high-power GaAs logic families with only an incremental speed advantage (see **Fig 3**). But E-D GaAs logic families, such as DCFL, offer an increase in complexity along with less power consumption. Therefore, it appears that a technology that was heralded for its speed advantage over silicon ECL, may find its best opportunity by offering more complexity, lower power, and higher manufacturing yields than ECL.

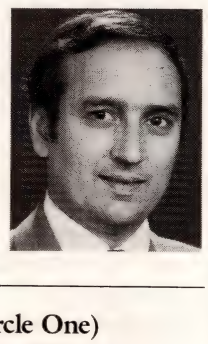
EDN

Reference

1. Singh, HP, et al, "A comparative study of GaAs logic families using universal shift registers and self-aligned gate technology," IEEE GaAs IC Symposium, pg 11, 1986.

Author's biography

Louis R Tomasetta is the president and CEO of Vitesse Semiconductor Corp. He has been at this position for four years since coming from Rockwell International. He has a BS, an MS, and a PhD from MIT. A member of the IEEE, he has been granted one patent.



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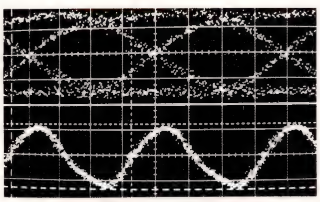

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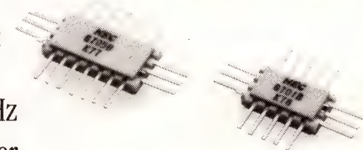

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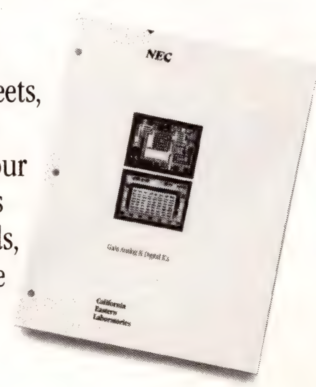

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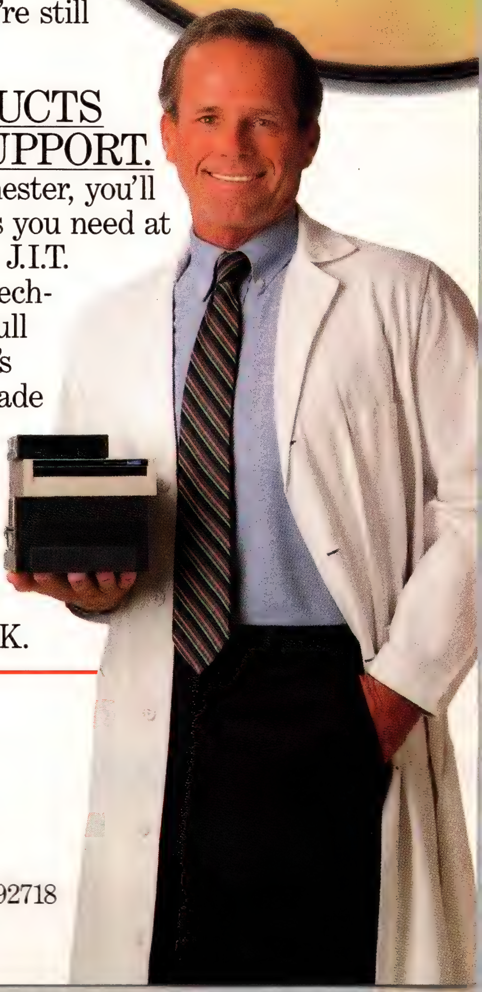

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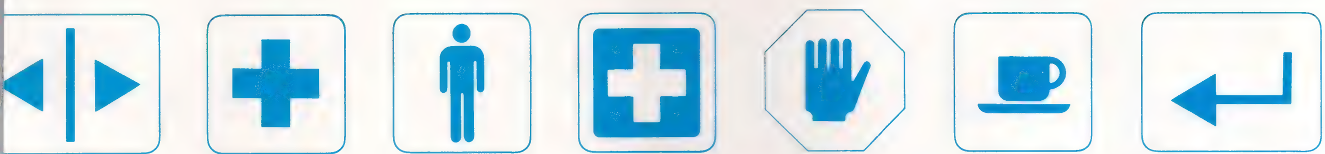

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Simple calculator acts as low-speed counter

J N Lygouras
University of Thrace, Xanthi, Greece

By adding a handful of inexpensive components, you can transform a 4-function calculator into a low-speed counter or tachometer. Note, however, that the calculator must have a constant-calculation feature for this scheme to work.

Fig 1 illustrates the scheme. In **Fig 1a,** a series of 555 timers produces a string of pulses **(Fig 1b),** which key the calculator. When you press the reset switch, S_1, its negative-going edge triggers the first 555 timer, IC_1, making its output go high for about 23 msec. This high level closes electronic switch S_2. This closure is equivalent to pressing the calculator's zero digit.

In a similar fashion, the circuit sequentially activates the plus and one keys. The negative-going output of the third 555 timer, IC_3, triggers the fourth 555 timer, IC_4. Triggering IC_4 enables electronic switch S_5, which routes the input pulses to the equals key for the duration of IC_4's time period. This sequence is equivalent to your pressing the calculator's keys as shown in **Fig 2,** where N is the number of counted pulses that correspond to the final display on the calculator at the end of IC_4's time period, T_C.

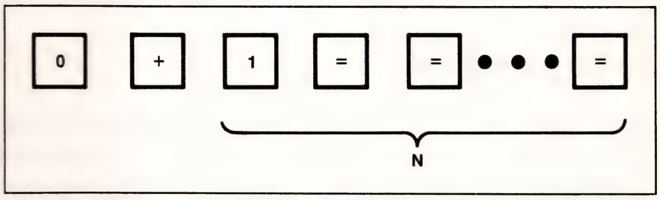

Fig 2—The circuit shown in Fig 1 *mimics the key strokes shown here.*

You can add the optional circuit to convert the counter to a tachometer. The Schmitt trigger shapes pulses from an engine's contact points. You must divide the points' signal by four because the calculator's maximum counting frequency is 20 Hz. For example, a 4-stroke, 4-cylinder engine running at 1000 rpm would generate 33.3 sparks/sec. Of course, if you divide the incoming pulse stream by four, you must increase IC_4's counting period by a factor of four to compensate. **EDN**

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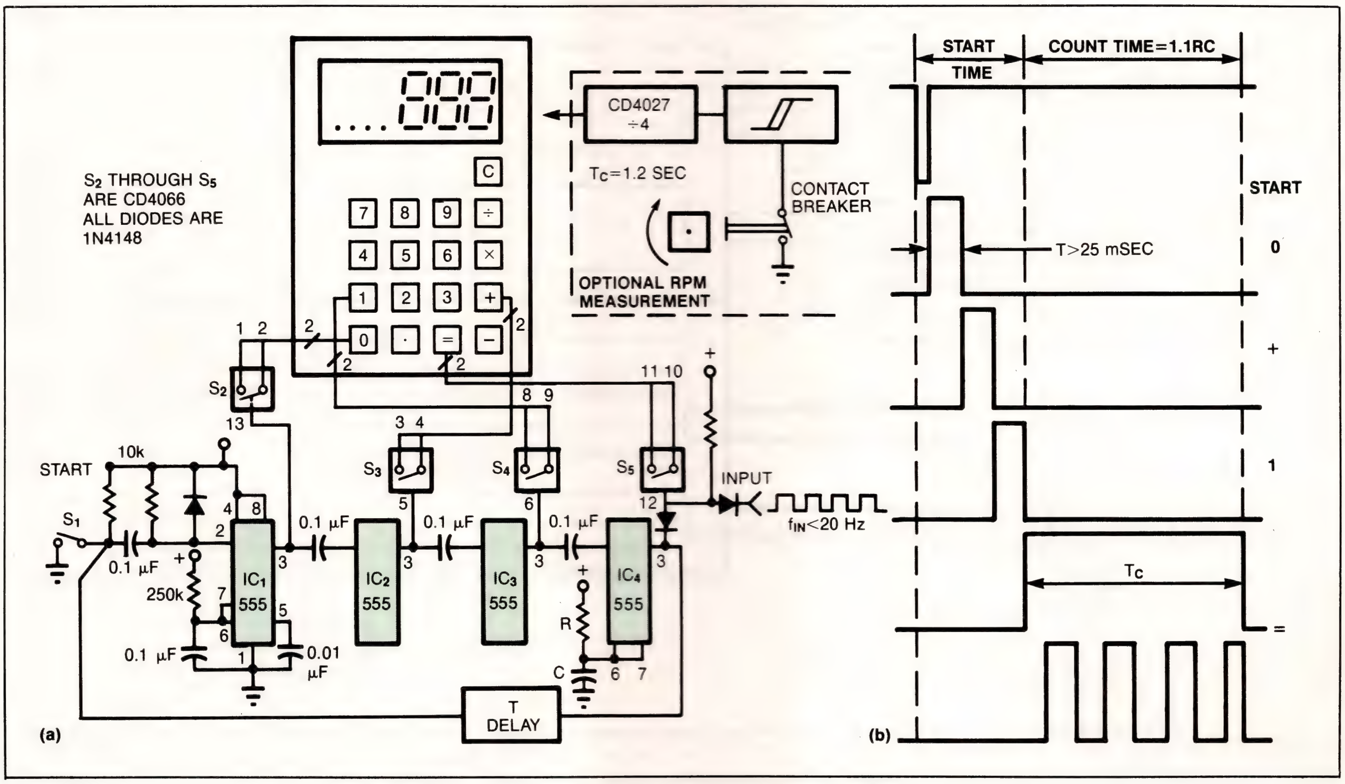

Fig 1—Electronic switches, triggered by 555 timers *and an incoming pulse train, turn a simple 4-function, constant-calculation calculator into a low-speed counter or, optionally, a tachometer.*

Circuit renders ROM contents secure

R B Srinivas,
Kalpakkam, India

If you are designing ASICs having memory elements, you can render those memory elements immune to dumping by incorporating a simple hardware/software scheme. This data-locking scheme blocks the reading of a device's memory contents by taking advantage of the fact that an external agent attempting to pirate a memory element's contents accesses each and every memory location while an onboard μP generally does not.

A data pirate can easily get a dump of commercially available data-protecting EPROMs by hot-wiring one of your boards and taking control of its EPROM in DMA fashion after the onboard μP has first unlocked the EPROM with its key. The scheme presented here is immune to such tactics and requires no manager chip, as do the commercial data-locking EPROMs.

The mechanism senses an unauthorized dump of the memory by triggering on accesses to ROM addresses that the μP's program never uses. The block diagram in **Fig 1** shows an example of the logic elements, outlined in heavy lines, that you must add to an ASIC that contains a 4k-byte ROM macrocell (2732 type).

The magnitude comparators, $MC_{1\text{-}16}$, compare the incoming address and a security code. These security codes are unused addresses you have previously stored. If any magnitude comparator senses a match, it permanently disables the ASIC's select logic via the 16-input OR gate and programmable switch, FS_1.

Note that the sixteenth control register's highest order bit also feeds back into the select logic to seal the control registers. This bit gets set when you program the sixteenth control register. After being programmed, this bit sets the select logic so that you can no longer write to the control registers. **EDN**

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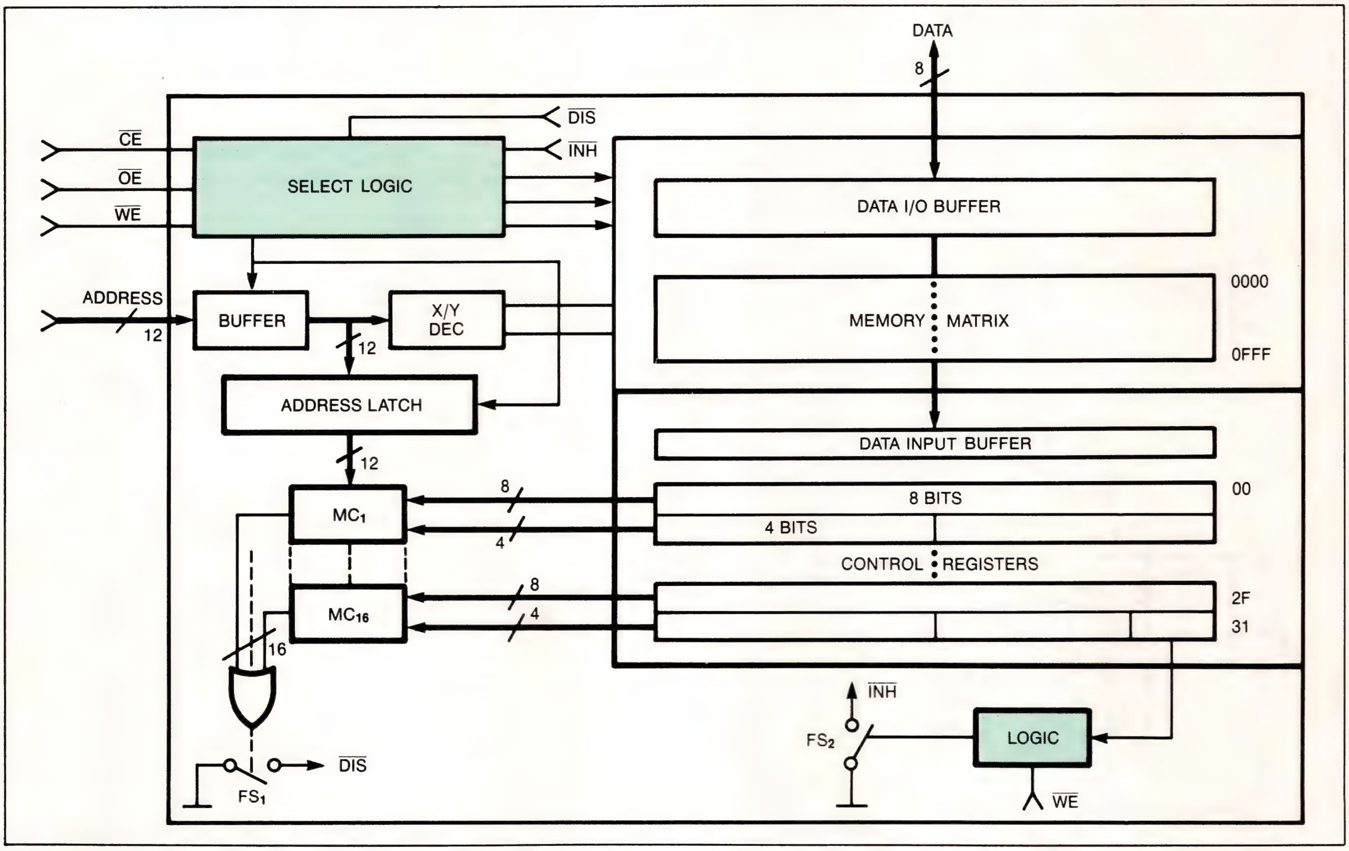
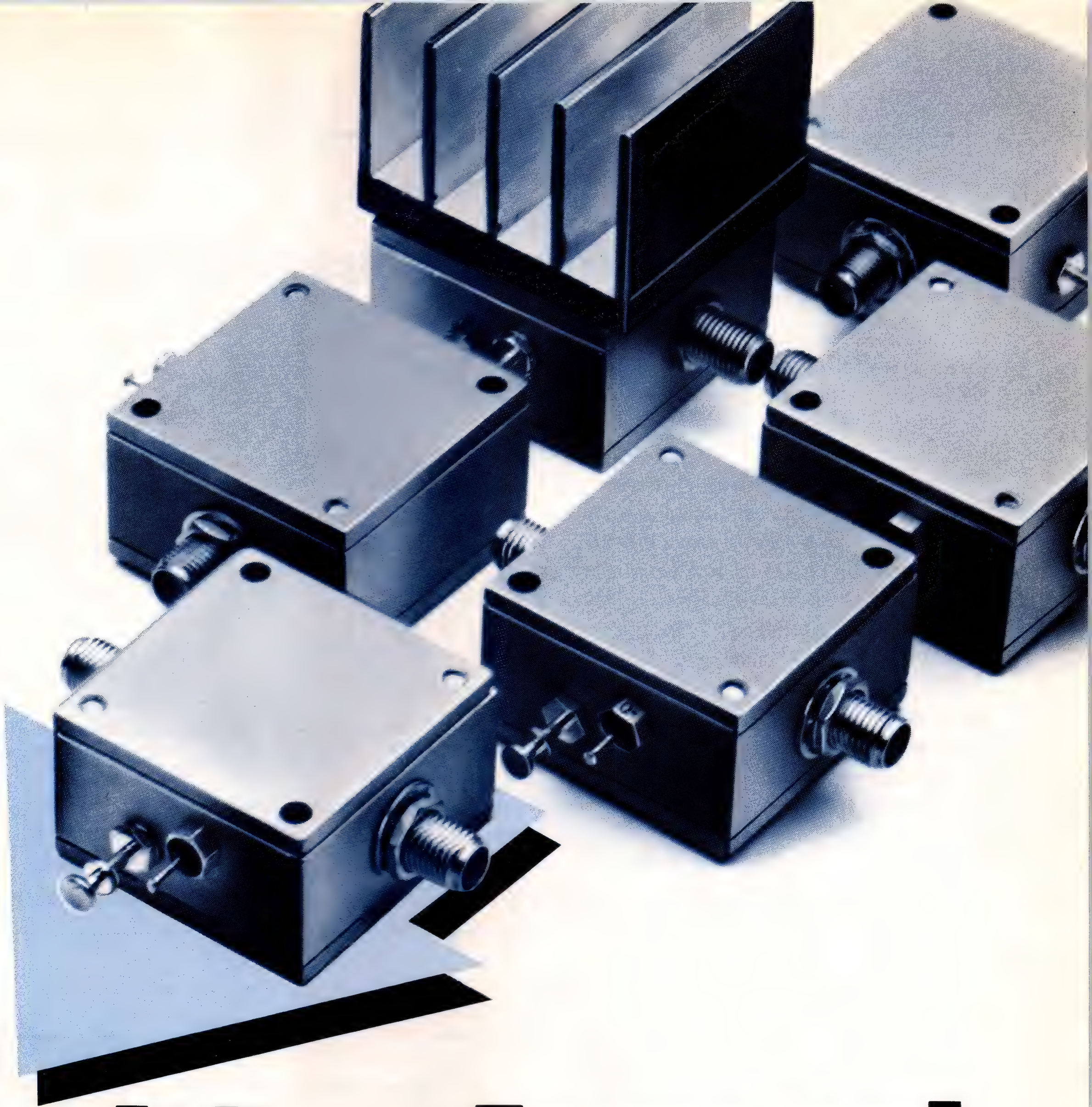


Fig 1—Adding a set of control registers and magnitude comparators to an ASIC that has a memory element can render the memory immune to data pirating. The control registers contain unused memory addresses. If a pirate attempts to access one of these unused program locations, the magnitude comparator sets a programmable switch that permanently disables the ASIC's select logic.



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ZFL-1000H	10-1000	28	+20	5.0	219.00	1-9
ZFL-500HLN	10-500	19	+16	3.8	99.95	1-24
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CIRCLE NO 199

ECL circuit calibrates phase meters

Miroslaw Sadowski
Warsaw University of Technology,
Warszawa, Poland

The circuit in **Fig 1** uses high-speed ECL devices to produce a pair of precision phase-shifted periodic signals, which prove useful for calibrating phase meters. This circuit has been tested with input signals ranging from 16 Hz to 96 MHz (1-Hz to 6-MHz output frequency). At a 6-MHz output frequency, a 0.1-nsec phase shift has about 0.2° accuracy.

The circuit divides the reference input by 16 to produce the output frequency. You use switches S_1 through S_4 to set the phase shift between the two outputs from 0° to 337.5° in 22.5° steps. The buffers in the clock line to the D flip-flops delay the clock signal to synchronize the flip-flops' inputs to the counters' outputs.

The simple Schmitt-trigger circuit in **Fig 2** allows you to slave the phase-shift generator to your test system's signal generator. **EDN**

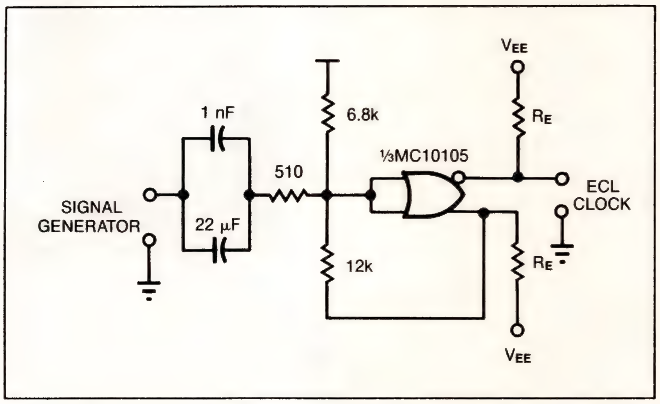

***Fig 2—You can slave the circuit in Fig 1** to your system's signal generator with this simple Schmitt trigger.*

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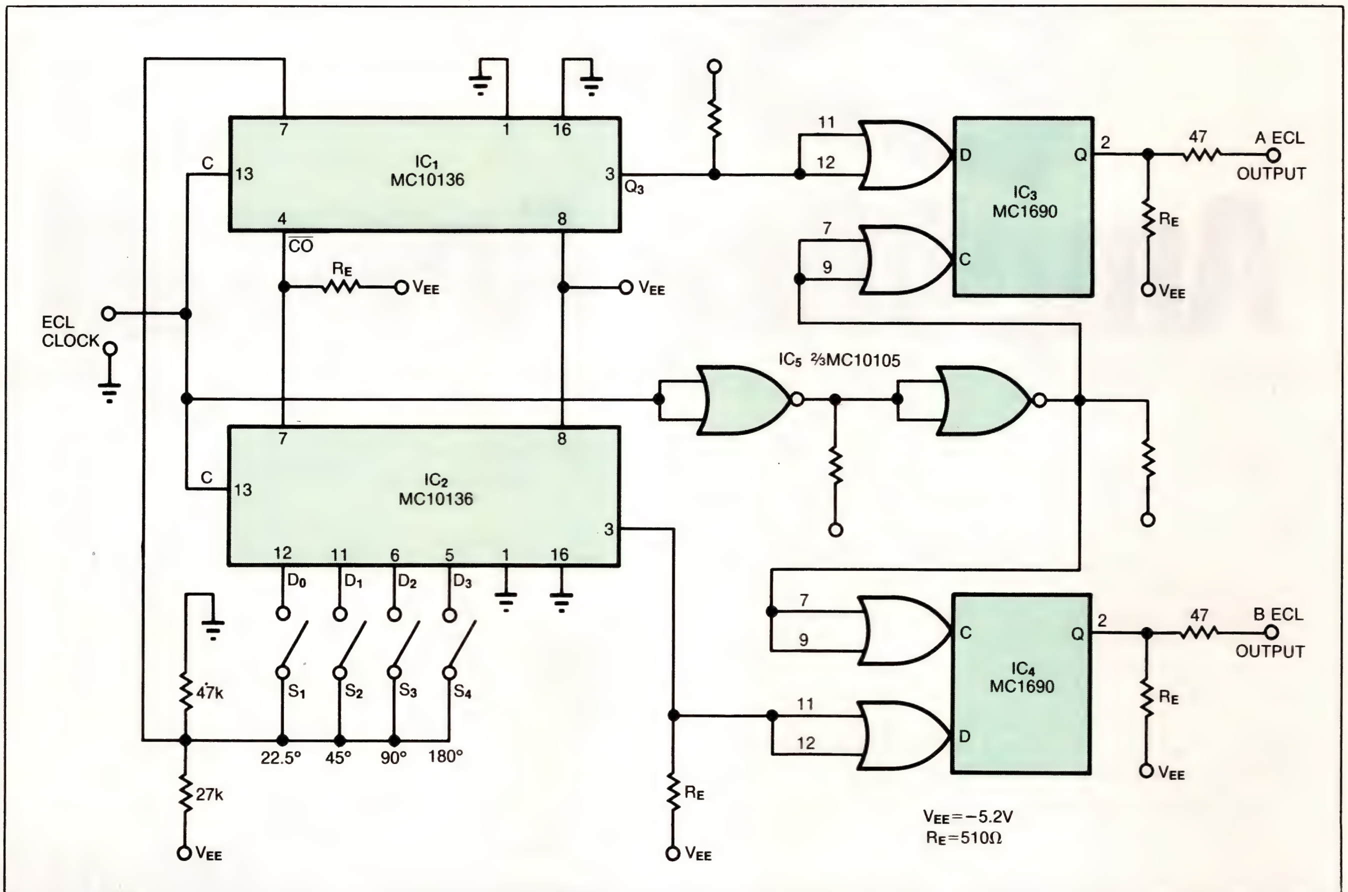

***Fig 1—This high-speed ECL circuit** develops a pair of phase-shifted square waves suitable for calibrating phase meters. By setting switches S_{1-4}, you can add programmable delay to the signal path through IC_2.*

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Cache-tag RAM is content-addressable

Steven Bennett
Integrated Device Technology Europe, Leatherhead, Surrey, UK

A 7174S35 cache-tag RAM forms the heart of a content-addressable memory. You can use this content-addressable memory in a µP-based system as a memory-mapped peripheral to vastly speed the searching of tables for data matches.

A content-addressable memory provides a diametrically opposite address-contents correlation from that of a conventional memory. If you supply a conventional memory with an address, it will return the address's data; if you supply a content-addressable memory with data, it will return the address in the memory where the data are stored (or, optionally, addresses in the event of multiple instances of a given datum).

Obviously, a content-addressable memory must access every location in its memory and test each location's contents against the data you supply. Although you can do such a search in software, the hardware-based design **(Fig 1)** is much faster. This design can check all 8k content-addressable memory locations in 409.6 µsec max.

Operating this content-addressable memory involves two distinct phases: loading and verifying the content-addressable memory and performing data matches. Loading the content-addressable memory begins with an active-low reset from the µP. You must clear the entire content-addressable memory to avoid generating spurious matches on obsolete data.

To load data, you first write a 13-bit address to the address latch IC_3 and, at the same time, set the 14th bit, PE (parallel enable), to the counter (IC_4 through IC_7) high. Setting PE high jams the 13-bit address into the counter, stops the counter, and impresses the 13-bit address on the RAM's (IC_8 and IC_9) address port. A second write, this time to IC_1, the data-transceiver latch, allows a 16-bit data word to flow through to the RAM's data port. At the same time, strobing the RAM's $\overline{WE}$ input via the decoder IC_{10} writes the data into the RAM.

Clearing the 14th bit latched into IC_3 releases the counters to continue cycling addresses. IC_3, a 49C602, is a bidirectional, 16-bit latched transceiver. Therefore, you can manipulate the 14th bit as part of a read-modify-write cycle (or clear the transceiver by writing 00_{HEX} to it).

Reading the content-addressable memory to verify data is similar to writing. You first load an address into the address latch IC_3, again setting the PE bit to jam the address into the counter. At this point you can read the 16-bit data word via IC_1 by setting the appropriate input to the IC_{10} decoder.

After loading and verifying the content-addressable memory's RAM, you can use the content-addressable

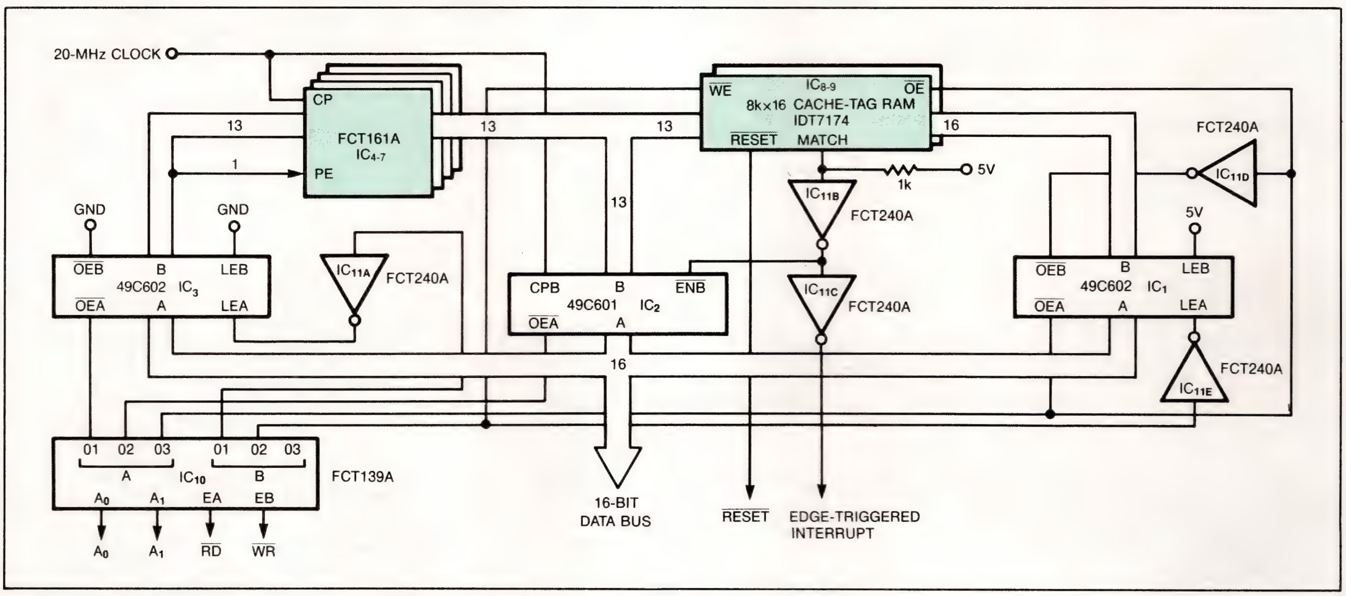

Fig 1—This content-addressable memory accepts a data word *in IC_1. The counter, $IC_{4\text{-}7}$, then begins cycling the RAM through all of its 8k addresses (in 409.6 µsec max) until the RAM finds a matching data word. The RAM then latches the address of the matching word into IC_2 for reading by the system µP.*

LINEAR TECHNOLOGY

DESIGN NOTES

Number 11 in a series from Linear Technology Corporation June, 1988

Achieving Microamp Quiescent Current in Switching Regulators

Jim Williams

Many battery powered applications require very wide ranges of power supply output current. Normal conditions require currents in the ampere range, while standby or "sleep" modes draw only microamperes. A typical lap top computer may draw 1 to 2 amperes running while needing only a few hundred microamps for memory when turned off. In theory, any switching regulator designed for loop stability under no-load conditions will work. In practice, a regulator's relatively large quiescent current may cause unacceptable battery drain during low output current intervals.

Figure 1 shows a typical flyback regulator. In this case the 6V battery is converted to a 12V output by the inductive flyback voltage produced each time the LT1070's V_{SW} pin is internally switched to ground. An internal 40kHz clock produces a flyback event every 25μs. The energy in this event is controlled by the IC's internal error amplifier, which acts to force the feedback (FB) pin to a 1.23V reference. The error amplifiers high impedance output (the V_C pin) uses an RC damper for stable loop compensation.

This circuit works well but pulls 9mA of quiescent current. If battery capacity is limited by size or weight this may be too high. How can this figure be reduced while retaining high current performance?

A solution is suggested by considering an auxiliary V_C pin function. If the V_C pin is pulled within 150mV of ground the IC shuts down, pulling only 50 microamperes. Figure 2's special loop exploits this feature, reducing quiescent current to only 150 microamperes. Here, circuitry is placed between the feedback divider and the V_C pin. The LT1070's internal feedback amplifier and reference are not used. Figure 3 shows operating waveforms under no-load conditions. The 12V output (trace A) ramps down over a period of seconds. During this time comparator A1's output (trace B) is low, as are the paralleled inverters. This pulls the V_C pin (trace C) low, putting the IC in its 50μA shutdown mode. The V_{SW} pin (trace D) is high, and no inductor current flows. When the 12V output drops about 20mV, A1 triggers and the inverters (74C04) go high, pulling the V_C pin up and turning on the regulator. The V_{SW} pin pulses the inductor at the 40kHz clock rate, causing the output to abruptly rise. This action trips A1 low, forcing the V_C pin back into shutdown. This "bang-bang" control loop keeps the 12V output within the 20mV ramp hysteresis window set by R3-R4. Diode clamps prevent V_C pin overdrive. Note that the loop oscillation period of 4-5 seconds means the R6-C2 time constant at V_C is not a significant term. Because the LT1070 spends almost all of the time in shutdown, very little quiescent current (150μA) is drawn.

Figure 4 shows the same waveforms with the load increased to 3mA. Loop oscillation frequency increases to keep up with the loads sink current demand. Now, the V_C pin waveform (trace C) begins to take on a filtered appearance. This is due to R6-C2's 10ms time constant. If the load continues to increase, loop oscillation frequency will also increase. The R6-C2 time constant, however, is fixed. Beyond some frequency, R6-C2 must average loop oscillations to DC.

Figure 5 plots what occurs, with a pleasant surprise. As output current rises, loop oscillation frequency also rises until about 500Hz. At this point the R6-C2 time constant filters the V_C pin to DC and the LT1070 transitions into "normal" operation. With the V_C pin at DC it is convenient to think of A1 and the inverters as a linear error amplifier with a closed loop gain set by the R1-R2 feedback divider. In fact, A1 is still duty cycle modulating, but at a rate far above R6-C2's break frequency. The phase error contributed by C1 (which was selected for low loop frequency at low output currents) is dominated by the R6-C2 roll off and the R7-C3 lead into A1. The loop is stable and responds linearly for all loads beyond 80mA. In this high current region the LT1070 behaves like Figure 1's circuit.

The loop described provides a controlled, conditional instability to lower regulator quiescent current by a factor of 60 without sacrificing high power performance. Although demonstrated in a boost converter, it is readily exportable to other configurations, (e.g., multi-output flyback, buck, etc.) allowing LT1070 use in low quiescent power applications.

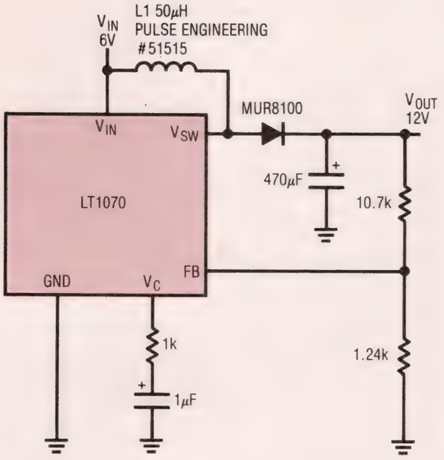

Figure 1. Typical LT1070 Flyback Regulator

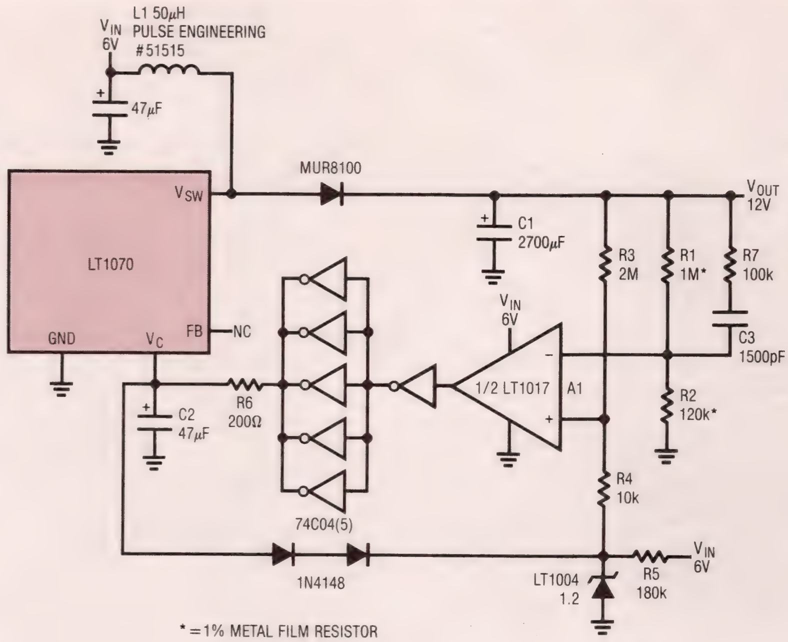

Figure 2. Low Quiescent Current Flyback Regulator

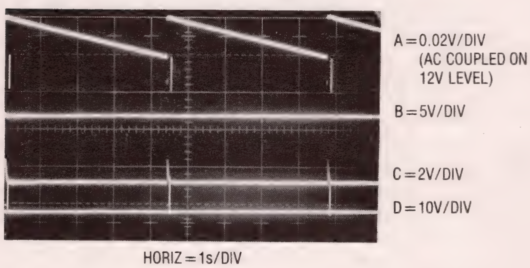

Figure 3. Waveforms at No Load for Figure 2 (Traces B and D Retouched for Clarity)

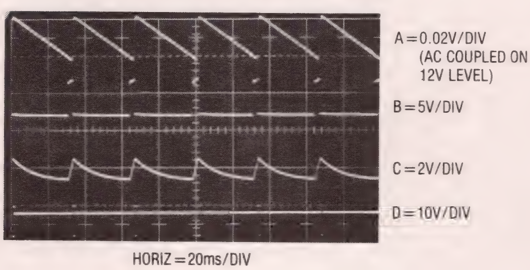

Figure 4. Waveforms at 3mA Load for Figure 2

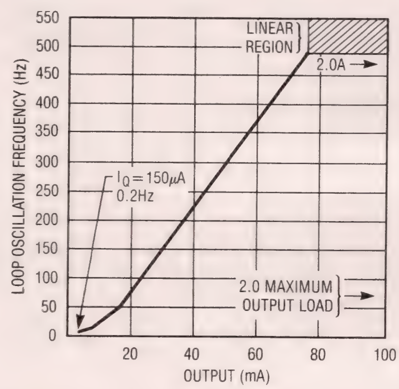

Figure 5. Output Current vs Loop Oscillation Frequency for Figure 2

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LINEAR TECHNOLOGY

memory to search for data matches. First, you write the data word to be searched for to the data latch, IC_1. When the counter sequence reaches an address of a data word in the RAM matching the search word, the RAM's built-in comparators pull the Match line to a logic one.

Asserting the Match line has two effects. First, the Clock Enable line of IC_2 goes to a logic zero, enabling the next clock edge to capture the value of the address counters (which corresponds to the address in RAM of the matching data). Second, Match sends an interrupt to the μP indicating that the content-addressable memory operation is complete. The μP can read out the address value held in IC_2.

If you desire to search for further occurrences of the data you can simply move the contents of IC_2 to IC_3 and begin searching again. **EDN**

To Vote For This Design, Circle No 748

Fortran routine manipulates bits

Joseph A Dennis
M/A Com Government Systems, San Diego, CA

Fortran subroutine BINA (**Listing 1**) takes a decimal number, converts it into a binary number, and stores it bit-wise in the array ADDRESS. BINA simulates, in software, a series of left-shift and test operations. This conversion and storage allows you to select any bit from the array ADDRESS for logic computations. Although BINA handles only numbers less than 256, you can easily extend it to cover larger numbers.

LISTING 1—SUBROUTINE BINA

```
C       SUBROUTINE TAKES THE DECIMAL VALUE OF ADR AND CONVERTS
C       IT INTO A BINARY VALUE AND STORES IN ARRAY ADDRESS(7:0).
C       ROUTINE USES A SHIFT LEFT OPERATION (MULTIPLY x 2) TO
C       EXAMINE CARRY OUT BUCKET BIT. IF BUCKET IS 1 THEN
C       DECIMAL VALUE OF IZ WILL BE EQUAL TO OR GREATER THAN
C       255. THE BUCKET VALUE IS STORED IN ARRAY ADDRESS(7.0)
C
C
        SUBROUTINE BINA(ADR, ADDRESS)
        INTEGER I,ADR,ADDRESS(0:7)
        INTEGER IZ
           IZ=ADR
        DO 10 I=7,0,-1             ; A SHIFT LEFT STARTS WITH BIT 7
2          IZ=2*IZ                 ; MULTIPLY SHIFTS VALUE TO LEFT BY 1 BIT
3          IF (IZ>255) THEN        ; EXAMINE CARRY OUT BUCKET
4             ADDRESS(I)=I         ; PLACE A "1" IN ARRAY BIT POSITION
5                IZ=IZ-256         ; CLEAR CARRY OUT BUCKET
6          ELSE
7             ADDRESS(I)=0         ; PLACE A "0" IN ARRAY BIT POSITION
8          END IF
10      CONTINUE
```

LISTING 2—ROUTINE THAT CALLS BINA

```
     DO  40 K=0,15                     ; CYCLE THROUGH ALL INPUTS
         ADR=-K                        ; CAN'T MESS WITH LOOP PARAMETER
         CALL BINA(ADR,ADDRESS)        ; INPUT ADR TO SUBROUTINE BINA
C                                        ARRAY ADDRESS(7:0) IS RETURNED
         OUTPUT(0)=[ADDRESS(3)+ADDRESS(2)]
                  +[ADDRESS(1) * ADDRESS(0)]
         TYPE 23,OUTPUT(0)
23       FORMAT("THE VALUE OF OUTPUT(0) IS",13)
40       CONTINUE
         STOP
         END
```

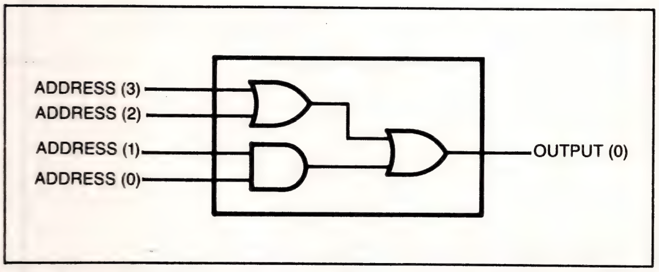

Fig 1—This simple circuit serves as an example of why you might need to manipulate individual bits in a Fortran program.

As an example of how to use BINA, consider the simple logic circuit in **Fig 1**. You can simulate this logic circuit with this equation:

$$\text{OUTPUT}(0) = [\text{ADDRESS}(3) + \text{ADDRESS}(2)] + [\text{ADDRESS}(1) * \text{ADDRESS}(0)]$$

where the plus sign equals a logic OR and the asterisk equals a logic AND.

To use this equation in a Fortran program, you must be able to selectively access each bit of the ADDRESS vector. The short Fortran program in **Listing 2** repeatedly calls BINA to set up the array ADDRESS and then plugs the ADDRESS vector into the logic equation. The short program automatically runs through all possible combinations of inputs. **EDN**

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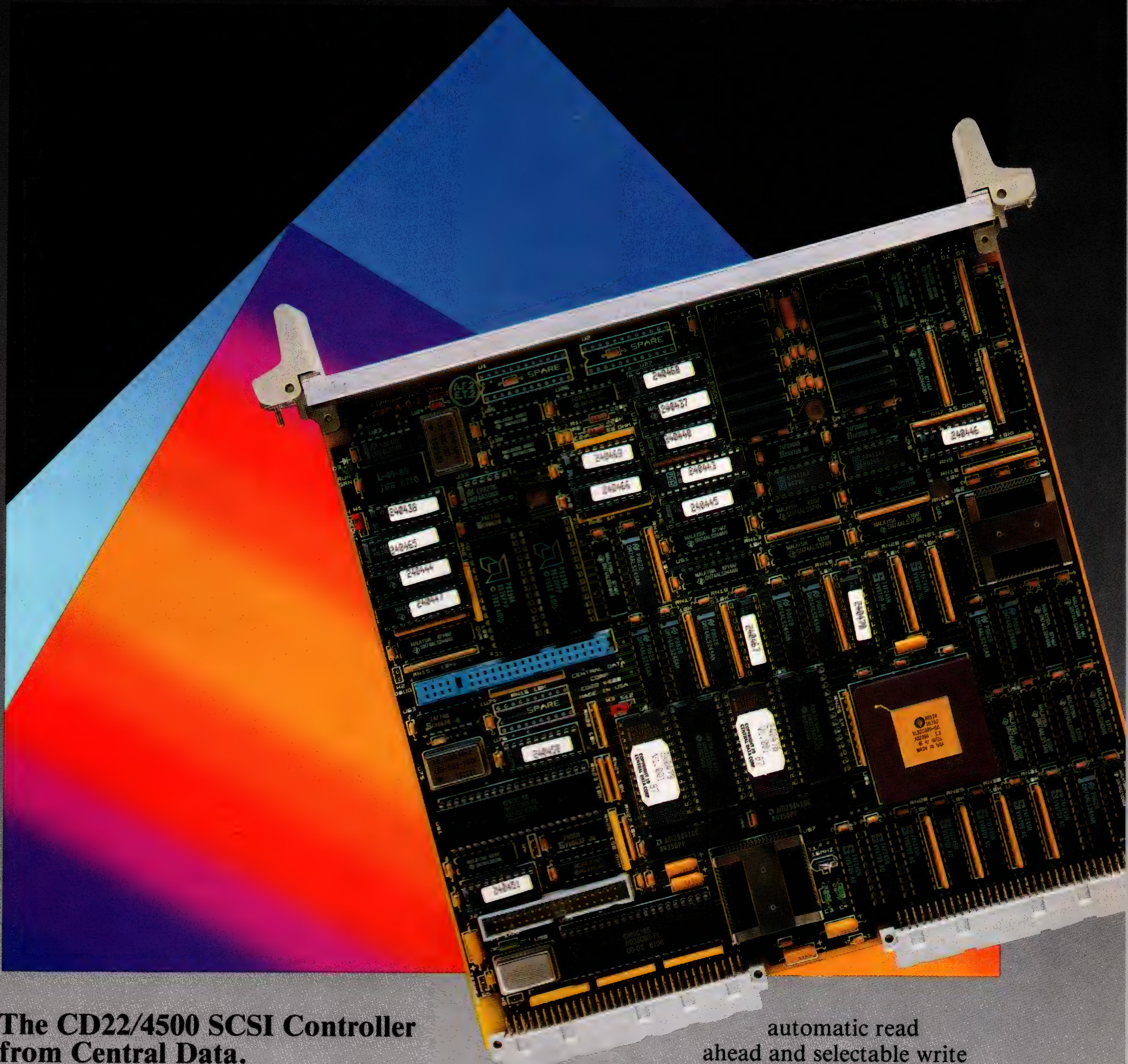

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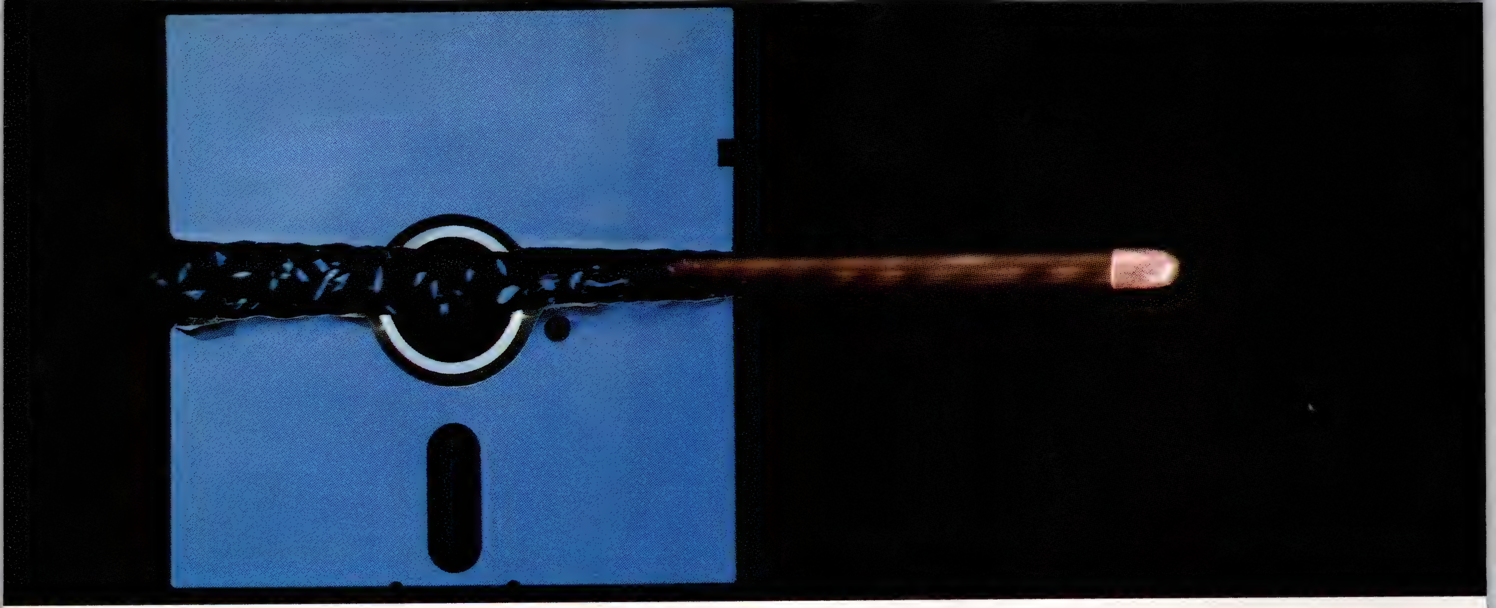

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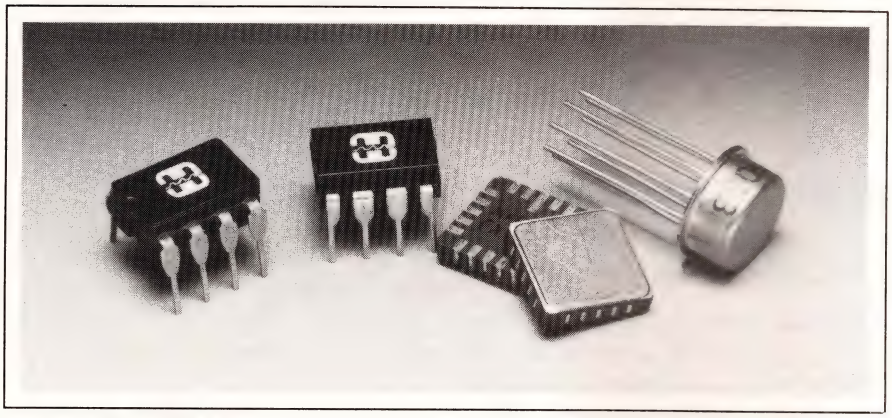


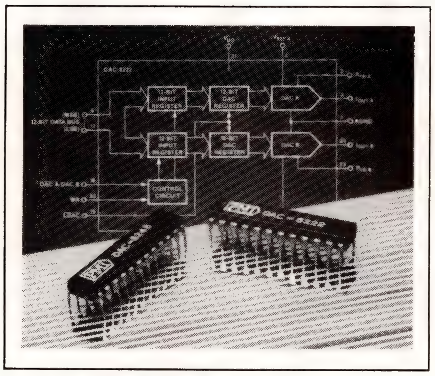
VIDEO OP AMP

- *Features 45-MHz unity-gain bandwidth*
- *Offers 150V/μsec slew rate*

The HA-2544 general-purpose op amp is optimized for video and other high-speed signals. The device features a unity-gain bandwidth of 45 MHz and a slew rate of 150V/μsec. When operating at 5 MHz, the unit has a differential gain error of less than 0.05 dB, a differential phase error of 0.1°, and a gain tolerance of 0.15 dB max. Its other video parameters include a typical 0.1-dB chrominance to luminance gain and a 5-nsec chrominance to luminance delay. The chip has an open-loop gain of 6 kV/V, an output voltage swing of ±10V from a ±15V supply, and a CMRR of 75 dB min and 89 dB typ. You can obtain it in an 8-pin TO-99, 8-pin plastic DIP, 8-pin ceramic DIP, or a 20-pin LCC. From $3.04 (100).

Harris Corp, Semiconductor Sector, Box 883, Melbourne, FL 32901. Phone (305) 724-7800.

Circle No 351



DUAL CMOS DACs

- *Permit selection of 8- or 12-bit data buses*
- *Provide double-buffered digital inputs*

The DAC-8222 and -8248 dual 12-bit D/A converters feature double buffering at their digital inputs. The devices offer a choice of 8- or 12-bit data-bus architectures to accommodate an 8-, 16-, or 32-bit μP. The 8222 has a 12-bit data bus that accepts a 12-bit word in a single byte, whereas the 8248 has an 8-bit data bus that accepts a 12-bit word in two bytes, an 8-bit byte followed by a 4-bit nibble, or 4-bits followed by 8 bits. Both DACs offer ±1-LSB gain accuracy with ±0.5-LSB nonlinearity, and they settle to within ±0.5 LSB of final value in less than 1 μsec for a 10V full-scale step change. The devices come in plastic or ceramic DIPs. Commercial-grade version, $11.60; military-grade version, $48 (100).

Precision Monolithics Inc, Box 58020, Santa Clara, CA 95052. Phone (408) 727-9222. TLX 713719541.

Circle No 352

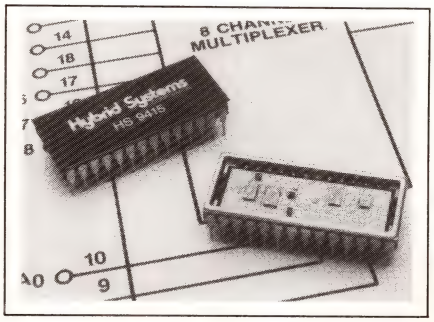
GaAs MULTIPLEXER

- *Meets Sonet standard*
- *Operates at 1.24G-bit/sec rate*

The VS8010 implements an 8 to 1 multiplexer and a 1 to 8 demultiplexer on a GaAs chip. The device contains control logic that meets the Sonet (synchronous optical network) standard at a 1.24G-bit/sec communication rate. The unit handles incoming 8-bit parallel data at rates to 155M bytes/sec and outputs a 1.24G-bit/sec serial bit stream. The chip also receives 1.24G-bit/sec data and converts it back to byte-wide parallel data. The demultiplexer portion of the chip contains the Sonet framing circuitry, which aligns the incoming serial data stream to the byte boundaries. Clock- and data-information are transmitted and received separately via a high-speed I/O to ensure synchronization. The device operates from standard ECL power supplies and comes in a 52-pin ceramic LCC. $980.

Vitesse Semiconductor Corp, 741 Calle Plano, Camarillo, CA 93010. Phone (805) 388-3700.

Circle No 353



DATA SYSTEMS

- *Feature 75-kHz throughput rates*
- *Provide 8-channel multiplexers and 12-bit ADCs*

Every Series SP9415 device constitutes a complete data-acquisition system housed in a single package.

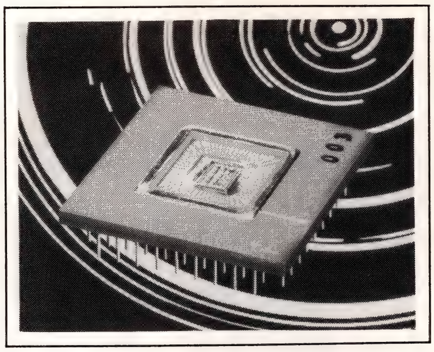
In addition to including an 8-channel multiplexer, a sample-hold amplifier, and a 12-bit A/D converter, each device provides control logic, a clock, and a reference. All the systems feature a 75-kHz throughput rate; you can expand a system's 8-channel input capacity by employing external multiplexers connected in series. You must specify fixed input ranges for the systems as follows: SP9415, 0 to 10V; SP416, ±5V; and SP417, ±10V. The sample-hold section of each system acquires signals in 1.5 μsec max to 0.01% for a 20V step. The aperture time equals 25 nsec, and the aperture uncertainty is 0.3 nsec. The devices' ADCs feature a 12-μsec conversion time, are μP compatible, and contain the interface logic necessary for direct connection to 8- or 16-bit buses. The devices come in 28-pin DIPs and operate from 5V and ±15V supplies. You can obtain each in two linearity-grade and temperature-range versions. $125 to $260 (100). Delivery, stock to 12 weeks ARO.

Sipex Corp, Hybrid Systems Div, 22 Linnell Circle, Billerica, MA 01821. Phone (617) 667-8700. FAX 617-667-8310.

Circle No 354

20-MHz CORRELATOR

- *Low-power CMOS*
- *Two speed grades*



Available in two speed grades (correlation rates) of 17 and 20 MHz, the TMC2220 is a 4×32-bit correlator with internal weighting and combining circuitry. Divided into four modules of 1×32 bits, each module contains mask and reference registers. The device produces a correlation score between the serial 32-bit input and the 32-bit reference pattern. The output from each module is multiplied by user-selected weighting factors and passed to the output section. The circuit then adds the four weighted results in combinations that you select. The final scaled and combined results are available from two parallel, 3-state output ports. The output is either 2's complement or unsigned magnitude. The device is available in a 68-pin pin-grid-array package. 17-MHz version, $61; 20-MHz version, $73 (1000).

TRW LSI Products, Box 2472, La Jolla, CA 92038. Phone (619) 457-1000.

Circle No 355

FREQUENCY INVERTERS

- *For secure voice applications*
- *Splits voice band*

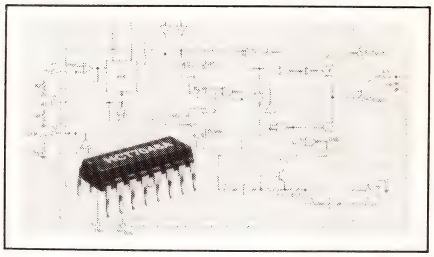
You can use the MX214 and MX224 variable split-band ICs for secure voice applications in mobile radios and telephony. In transmit mode, the devices use frequency-agile, seventh-order elliptic filters to split the 300- to 2700-Hz voice band into one of 32 pairs of sub-bands. The circuit inverts the frequency of the sub-bands and then recombines them in the output. In the receive mode, the circuit reverses the filtering process. You can configure the devices in fixed-code mode (constant sub-bands), or in rolling-code mode (sub-bands periodically changed via μP control). Both devices are single-channel, half-duplex types that require 5V CMOS power and draw 8 mA typ. A 300-Hz, on-chip highpass filter allows full compatibility with subaudible signaling schemes. The 22-pin MX214 requires serial loading of digital control functions; the 24-pin MX224 requires parallel loading. $15.30 (100).

MX-COM Inc, 4800 Bethania Station Rd, Winston-Salem, NC 27105. Phone (800) 638-5577; in NC, (919) 744-5050.

Circle No 356

HIGH-SPEED PLL

- *Includes VCO and lock detector*
- *High-speed CMOS construction*



The CD54/74HC/HCT7046A phase-locked loop IC contains a linear voltage-controlled oscillator, a lock-detector circuit, and two types of phase comparators. Depending on the duty cycle, designers can choose between an exclusive-OR phase comparator and an edge-triggered J-K flip-flop comparator. A NOR gate and envelope detector detect a locked-loop condition; when the loop is in lock, a high-level signal (logic 1) appears on pin 1 of the device. The signal and comparator inputs, which you can couple directly to large voltage signals, are provided for the phase comparator. When operated with a passive lowpass filter, the device forms a second-order PLL. Two versions of the device are available: The CD54/74HC7046A is suitable for CMOS designs; the CD54/74HCT7046A has the inhibit input adjusted for TTL designs. In the plastic DIP version, $2 (100).

GE Solid State, Route 202, Somerville, NJ 08876. Phone (201) 685-6562.

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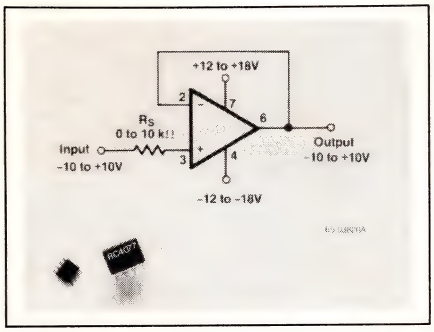


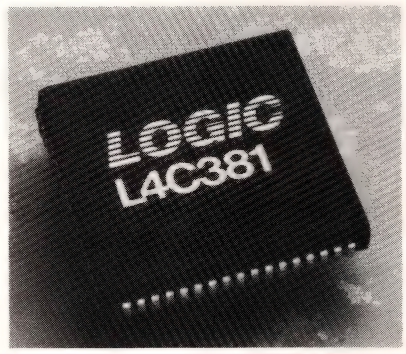
PRECISION OP AMP

- *Very low offset voltage*
- *Low power dissipation*

Equal or superior to competitive types in several important parameters, the RC4077 precision op amp features an offset voltage of $\pm 10\ \mu V$ (max) and an offset-voltage drift of $0.3\ \mu V/°C$ (max). The device achieves its offset-voltage specifications by the use of stable thin-film resistors that are trimmed during production. Other features include an input bias current of 2 nA (max), a minimum open-loop gain of 5M, and a maximum power dissipation of 50 mW. The RC4077 has a minimum CMRR of 120 dB and a PSRR of 110 dB. The op amp is available in LCC, SOIC, TO-99, and plastic and ceramic miniature DIPs. Processing to MIL-STD-883B is also available. Depending on the grade, from \$3 to \$18 (100).

Raytheon Co, Semiconductor Div, 350 Ellis St, Mountain View, CA 94043. Phone (415) 968-9211.

Circle No 358

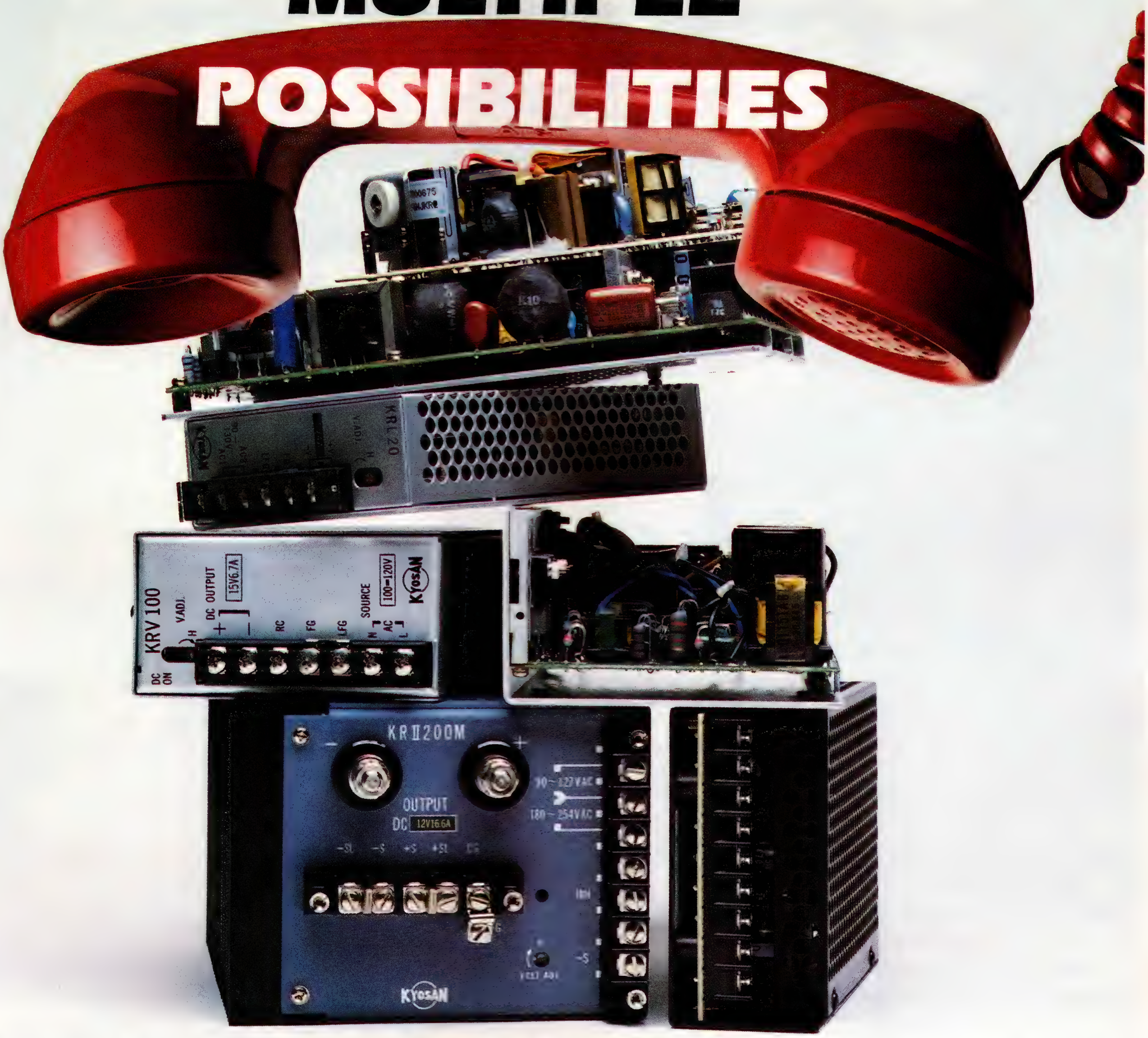


CMOS 16-BIT ALU

- *Provides 10 functions*
- *Offers two 16-bit inputs*

According to the manufacturer, the L4C381 is the industry's fastest CMOS 16-bit arithmetic logic unit (ALU). When operating in the flow-through mode, the device can perform any one of five arithmetic or five logical functions on two 16-bit inputs in 26 nsec, whereas when operating in the registered-add mode, it can complete a function in 20 nsec. These ten functions include subtraction, accumulation, and negation. Each of the two 16-bit inputs on the device has a register that allows the simultaneous loading of two data values from a 32-bit bus or of one data value at a time from a 16-bit bus. A register on the device's 16-bit output allows the chip

MULTIPLE POSSIBILITIES



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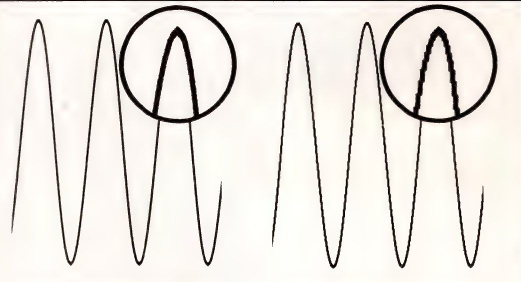

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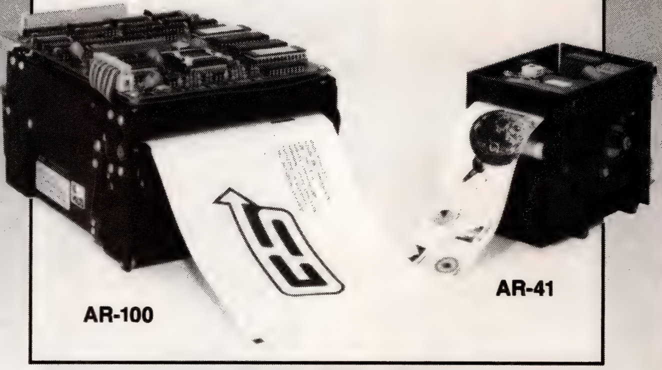

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Logic Devices Inc, 628 East Evelyn Ave, Sunnyvale, CA 94086. Phone (408) 720-8630.

Circle No 359

MICROCONTROLLER

- *Contains twice as much RAM and ROM as an 80C51*
- *Includes an IIC Bus interface*

The PCB83C652 8-bit CMOS microcontroller is fully compatible with the industry standard 80C51 microcontroller, but provides you with twice as much on-chip ROM and RAM, and an IIC Bus interface. The device has 8k bytes of program ROM and 256 bytes of volatile data RAM. As with the industry standard part, you can expand both the RAM and ROM off chip to 64k bytes. The device's 2-wire, serial IIC Bus interface allows you to use the microcontroller with a variety of other IIC Bus-compatible ICs. The PCB83C652's other on-chip functions are equivalent to those found in an 80C51 microcontroller. Manufactured in a CMOS process, the device has software-selectable idle and power-down modes in which typical current consumption is 5 mA and 50 μA, respectively. It is packaged in a 44-pin plastic leaded chip carrier or a 40-pin DIP. A quad flat-pack version and an extended temperature-range version are under development. Approximately DM 18 (50,000).

Philips, Components Division, Box 523, 5600 AM Eindhoven, The Netherlands. Phone (040) 757005. TLX 51573.

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Amperex Sales Corp, Providence Pike, Slatersville, RI 02876. Phone (401) 762-9000.

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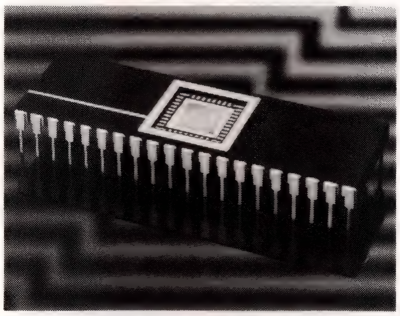


CONTROLLER CHIP

- *Broadband MAP interface*
- *Combines multichip functions*

The MC68184 broadband interface controller supports the Manufacturing Automation Protocol in real-time communications networking. The broadband network specified by MAP connects mainframes and data bases with carrier-band subnetworks. By combining the functions of as many as 50 SSI/MSI ICs into a single 40-pin DIP, the chip reduces the cost of a MAP broadband modem. The 10M bit/sec MC68184 implements the digital portion of the IEEE-802.4 broadband physical layer for standardized multivendor data-communications networking. The digital portion manipulates data and provides control for the RF transmitter and receiver. The de-

vice also features post-error correction, two loop-back modes, and 20 lines for receiver/transmitter control—including 13 user-defined lines. In a 40-pin plastic DIP. $20 (100).

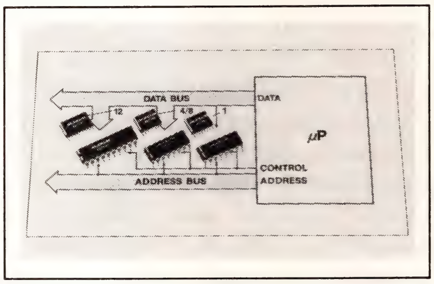
Motorola Inc, Technical Information Center, Box 52073, Phoenix, AZ 85072. Phone (602) 821-4406.

Circle No 362

12-BIT DACs

- *Provide three interfaces*
- *CMOS and TTL compatible*

The AD7542, 7543, and 7545 12-bit multiplying D/A converters interface with popular 8- and 16-bit µPs. Each of the converters offers a different interface technique. The 7542 features data inputs organized around three 4-bit bytes, the 7543 accepts data serially, and the 7545 supports a 12-bit parallel interface. These current-output D/A converters possess thin-film resistors that have guaranteed monotonicity and are laser trimmed to a maximum gain error of ±1 LSB and an integral linearity of ±0.5 LSB. The devices work with a 5V power supply and are TTL/CMOS compatible. They come in three electrical grades and temperature ranges. You can order them in small-outline packages or in plastic or ceramic DIPs. Including 24-hour, 150°C burn-in, $6.40 (100).



Maxim Integrated Products, 120 San Gabriel Dr, Sunnyvale, CA 94086. Phone (408) 737-7600.

Circle No 363

CRT CONTROLLERS

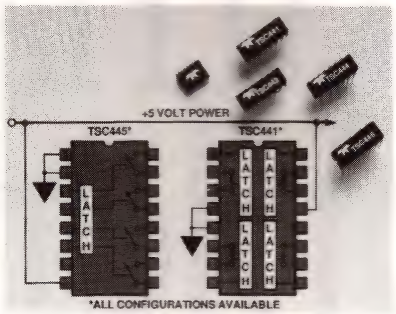
- *Provide 256 characters per row*
- *Operate at 5-MHz clock rates*

Suitable for use in color or monochrome alphanumeric CRT terminals, the SCN2672T and 2674T are enhanced versions of video controllers with the same part numbers. The devices generate the vertical and horizontal timing signals necessary for the display of interlaced or noninterlaced data on a CRT monitor. Both devices feature 256 characters per row, 1 to 16 raster lines per character, and 128 character rows per frame. The 2672T operates at a character clock rate of 5 MHz, the 2674T at 5.5 MHz. The 2674T also includes features such as bidirectional soft scrolling, double height/width modes, and RAM addressing for multiple-page operation. Both devices are fully pro-

grammable. You can order them in plastic DIPs and plastic leaded chip carriers. 2672T, $5; 2674T, $6 (100).

Signetics, Box 3409, Sunnyvale, CA 94088. Phone (408) 991-2000.

Circle No 364



ANALOG SWITCHES

- *Operate at 5V*
- *Feature low on-resistance*

The analog switches TSC441, 442, 443, 444, 445, 446, and 447, which feature on-chip latches and the ability to operate from a 5V supply, are suitable for use with µP-based systems. Each member of the series specs on-resistance of less than 175Ω at 25°C and leakage current of 10 pA typ. The 441 and 446 contain four independent and normally closed switches; the 442 and 445 contain four independent and normally open switches. The 443 and 447 provide two normally closed switches. The 444 provides two single-pole, three-position switches. All the switches incorporate a latch, which latches in the address input for each. If you don't need the latches, you can operate the switches in a transparent mode by tying the latch write-input low. You can obtain the devices in 14- and 16-pin plastic and ceramic DIPs or in surface-mount packages. Commercial-grade versions, $1.81; military-grade versions, $4.92 (100).

Teledyne Semiconductor, 1300 Terra Bella Ave, Mountain View, CA 94039. Phone (415) 968-9241. TWX 910-379-6494.

Circle No 365

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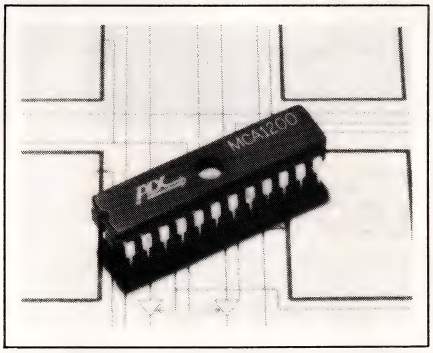


MICRO CHANNEL CHIP

- *Micro Channel interface*
- *Uses PLD technology*

Built from PLD technology, the MCA 1200 provides a master interface for the IBM Micro Channel circuitry. It includes the protocol logic, 24-mA drivers, and input buffers necessary for bus control and local arbitration of the Micro Channel interface. The CMOS device is μP independent and includes burst or single-cycle data-transfer capability. You can customize your interface by programming the device, using PLD programming tools such as ABEL, CUPL, and programmers from Data I/O and other manufacturers. The device will be available in the second quarter of 1988. Sample price, $26.

PLX Technology, 520 Weddell Dr, Suite 3, Sunnyvale, CA 94089. Phone (408) 747-1711.

Circle No 366

VIDEO CONTROLLER

- *Combines DRAM, VRAM, and CRT controls on a single chip*
- *Works with 16- and 32-bit μPs*

The SMJ34061, which is suitable for high-performance video-system control in military applications, integrates video RAM (VRAM), dynamic RAM (DRAM), and CRT controls on a single chip. The chip interfaces with the CRT, system memory, and the host processor in a graphics system. The combination of functions eliminates the need for separate text and graphics subsystems. The unit is compatible with any 16-bit or 32-bit processor. As an interface to the CRT, the chip provides programmable control of 256×256- to 4096×4096-line screen resolutions. It contains all the control functions needed to interface system memory and video memory to a monitor in bit-mapped graphics applications. You can also use the chip as a stand-alone DRAM controller to refresh VRAMs and DRAMs. Characterized for operation from −55 to 110°C, the device comes in a 68-pin ceramic pin-grid-array package. $135 (1000).

Texas Instruments, Semiconductor Group (SC-817), Box 809066, Dallas, TX 75380. Phone (800) 232-3200.

Circle No 367

64-BIT PROCESSOR

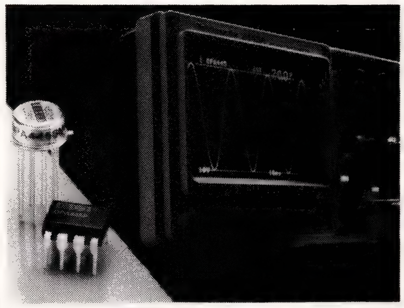
- *Floating-point CMOS type*
- *Features 100-nsec throughput rate*

The single-chip Am29C327 is a double-precision, 64-bit floating-point processor that provides a 100-nsec throughput rate and includes more than 70 instructions. It performs arithmetic and logical operations on 32- and 64-bit integers and supports the IEEE-754, IBM, and DEC D, F, and G formats. You can operate it in a flow-through or pipelined mode, ensuring high performance in both scalar and vector applications. The company is now shipping first samples and will provide general-customer samples by the third quarter. The device comes in a 169-pin pig-

grid-array package. $595 for 100-nsec version; $395 for 120-nsec version (100).

Advanced Micro Devices, Box 3453, Sunnyvale, CA 94088. Phone (408) 732-2400.

Circle No 368



HIGH VOLTAGE OP AMP

- *Operates from ±45V supplies*
- *Low input bias current of 50 pA*

Capable of operating over a supply-voltage range from ±10 to ±45V, the OPA445 op amp features FET input circuitry that lets you use high-impedance feedback networks, thus minimizing output loading effects. The device's input bias current is 50 pA max at room temperature and <100 nA at 125°C. Laser trimming limits the input offset voltage to 1 mV max, and the offset drift is 10 μV/°C. The device is unity gain stable and has a slew rate of 10V/μsec. It's available in industrial and military temperature ranges, and comes in either an 8-pin DIP or a TO-99 package. $3.80 (100).

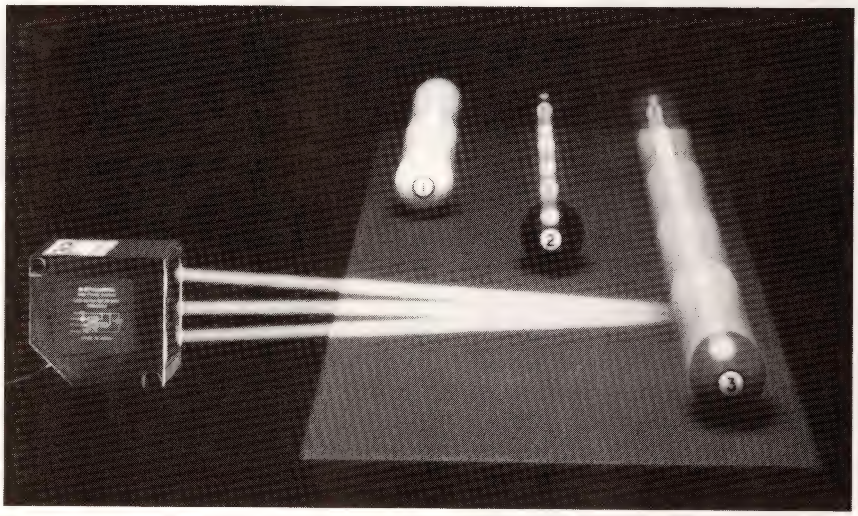
Burr-Brown, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. TLX 666491.

Circle No 369

COMPONENTS & POWER SUPPLIES

SENSORS

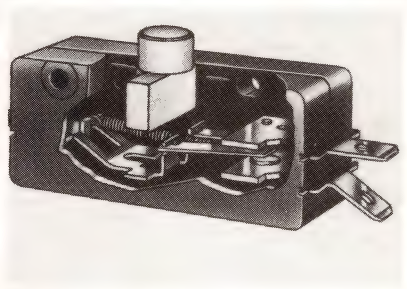
- *Sensing capability ranges from 1 in. to 2 ft*
- *Background movement has no effect on performance*



MQ triple-beam photoelectric sensors have a sensing capability ranging from 1 in. to 2 ft, and feature operating speeds of 200 operations/sec max. Available in three versions, the units employ an optical-triangulation-measurement principle that provides consistent range detection regardless of the target object's color, material, or surface condition. The devices have a preset sensing region so background movement has no effect on operation. The range-measurement technique also minimizes the effects of soiled lenses because detection is based on light angle rather than light intensity. $75 to $100 (100).

Aromat Corp, Industrial Products Div, 629 Central Ave, New Providence, NJ 07974. Phone (201) 464-3550.

Circle No 375



SWITCHES

- *You can choose from silver or gold contacts*
- *Available in spst and spdt configurations*

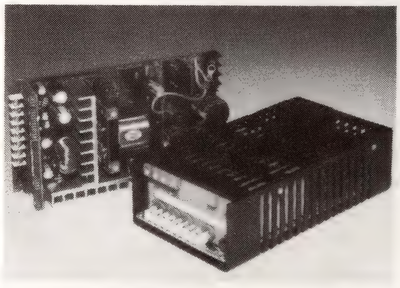
DL Series general-purpose switches are available with either silver contacts rated for 15 or 25A or gold crosspoint contacts rated at 0.1A. All ratings are at 125 or 250V ac. The thermoplastic case features a hinged design, which eases installation of different style levers and actuators—both are available in a choice of two pivot positions. The devices are available with a wear-resistant thermoplastic button actuator. The company can design special button lengths, forms, and colors to meet any requirement. The switches are offered in either spst or spdt configurations (NO or NC). $0.95 (1000), for a unit that includes actuator and silver contacts rated for 15A.

Cherry Electrical Products, 3600 Sunset Ave, Waukegan, IL 60087. Phone (312) 360-3518.

Circle No 376

POWER SUPPLIES

- *Deliver 150W from a small case size*
- *Cope with light loads and high peak output currents*



RL150 Series switch-mode power supplies deliver 150W of output power from a package that measures only 214×60×117 mm (8.4×2.4×4.6 in.). All versions of the supply have a 5V main output that can deliver a maximum continuous current of 15A. Secondary outputs are either ±12V and 12V, ±12V and 24V, ±12V and −5V, or ±15V and −5V. You can trim the output voltages by ±5%. The supplies will operate with a main output load as low as 1.2A with all other outputs unloaded, and can cope with the high peak current requirements of, for example, disk drives. Other features include 75-kHz FET switching, warm- and cold-start inrush-current control, and line input failure signalling. Load regulation for a 40% change on a 60% load is ±0.5% for the main output, ±2% for the split positive and negative supplies, and ±0.5% for the single supply. The supplies operate from ac line input voltages of 99 to 132V, or 187 to 265V, and have a line regulation of ±0.1% for a

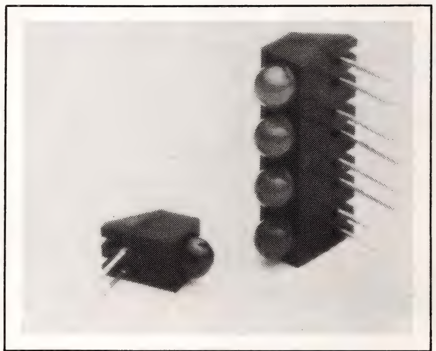
±15% line-input change. £90.24 (100).

Coutant Electronics Ltd, Kingsley Ave, Ilfracombe, EX34 8ES, UK. Phone (0271) 65656. TLX 46310.

Circle No 377

Qualidyne Systems Inc, 3055 Del Sol Blvd, San Diego, CA 92154. Phone (619) 575-1100. TLX 709029.

Circle No 378



LED INDICATORS

- *Available in four colors*
- *Right-angle design accommodates pc board mounting needs*

The Jupiter LL500 Series of right-angle indicators incorporates a tinted, diffused T-1¾ LED in a black plastic housing that sits flush on a pc board. The single- and 4-position indicators are available in red, high-efficiency red, yellow, and green, and are side-stackable for array applications. \$0.17 and \$0.52 (1000) for single- and 4-position red indicators, respectively. Delivery, stock to six weeks ARO.

IEE Inc, Component Products Div, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311.

Circle No 379

DIP SWITCHES

- *Feature 94V-0 UL rated materials*
- *Available in 2- to 10-position versions*

Designed for surface mounting on pc boards, these DIP switches are available in 2- to 10-position ver-

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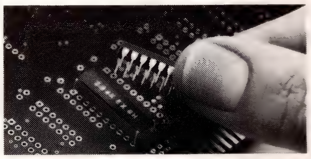
For applications in severe conditions, nothing can take whatever the environment dishes out like Rogers new Micro/Q 2000 Flat Ceramic Decoupling Capacitor.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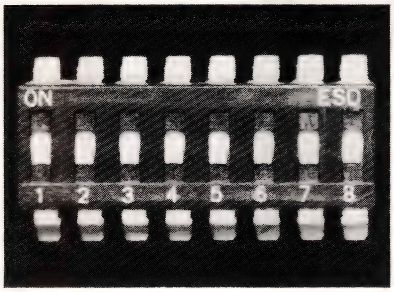
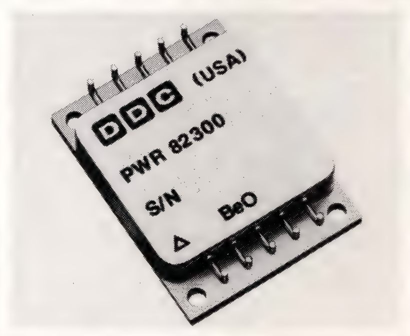
sions. The switches feature gold contacts for reliable performance and employ 94V-0 UL-rated housing materials. The contacts will switch 100 mA at 5V dc. Contact resistance equals 50m Ω initially and 100m Ω at end of life. The devices' insulation resistance and dielectric strength spec at $10^9\Omega$ and 500V dc, respectively. They operate over a −25 to



+70°C range. \$1.25 (1000) for a 10-position unit. Delivery, six to eight weeks ARO.

LZR Electronics Inc, 8174 Beechcraft Ave, Gaithersburg, MD 20879. Phone (301) 921-9440.

Circle No 380



BRIDGE RECTIFIERS

- *Feature a 35A output*
- *Available in four versions*

The PWR-82300 Series power hybrid bridge rectifiers feature a 35A output. Each unit contains four Schottky barrier diodes connected in a single-phase, full-wave bridge and measures just 2.5 in². The rectifiers are manufactured in accordance with MIL-M-38510 and MIL-STD-883C. Junction-to-case thermal resistance is less than 0.85°C/W. The devices are available in 20, 40, 60, and 80V full-bridge configurations. Operating range specs at −55 to +125°C. \$700. Delivery, stock to 120 days ARO.

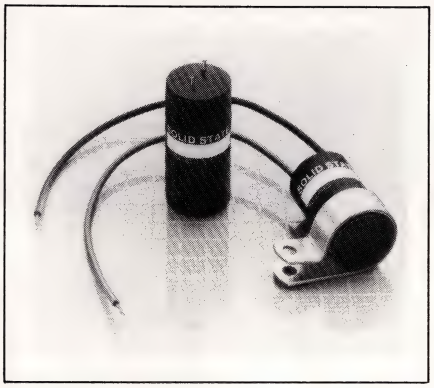
ILC Data Device Corp, 105 Wilbur Pl, Bohemia, NY 11716. Phone (516) 567-5600.

Circle No 381

TIMERS

- *Offer fixed delays of 0.05 to 180 sec*
- *Feature ±5% repeat accuracy*

Designed for pc-board mounting, the MSM Series solid-state timers feature fixed delays ranging from 0.05 to 180 sec. The devices' tolerance specs at ±15% and repeat accuracy equals ±5%. Units are avail-



able that operate on 12 and 24V dc or 24, 120, and 230V ac. The timers operate over a −20 to +60°C range. The devices' load current equals 0.5A at 25°C and 0.25A at 60°C; their holding current specs at 40 mA min. The devices' dielectric-breakdown and insulation-resistance figures are 1500V rms and $10^8\Omega$, respectively. $5 (500).

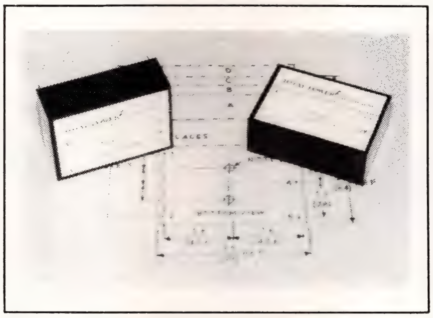
SSAC Inc, Box 1000, Baldwinsville, NY 13027. Phone (315) 638-0100.

Circle No 382

POWER SUPPLIES

- *−25 to +71°C operating range*
- *Features 10W output capability*

The 12 models in the TP Series single-output power supplies offer 5, 12, and 15V outputs. The supply's design allows the units to drive tungsten loads without any voltage dropout problems. The supplies have a 125 to 150V ac input range and operate over −25 to +71°C. Line and load regulation specs at 0.05 and 0.2%, respectively, and ripple and noise equal 1 mV rms max. The units are available for pc board or chassis mounting. The latter versions come with a terminal barrier strip. The supplies meet UL and CSA requirements. From $35.82 (100).



Total Power International Inc, 418 Bridge St, Lowell, MA 01850. Phone (617) 453-7272.

Circle No 383

DC/DC CONVERTERS

- *Offer three outputs*
- *300,000 hour MTBF*

LP-315 Series 25W dc/dc converters have an MTBF of 300,000 hours. Six models in the line offer triple outputs of 5V at 4A and either ±12 or ±15V at 0.25A. The devices' switching frequency equals 500 kHz. Their other features include 500V dc I/O isolation, 75% efficiency, ±0.3% line regulation, and ±0.5% load regulation. Overvoltage and indefinite output short-circuit protection are

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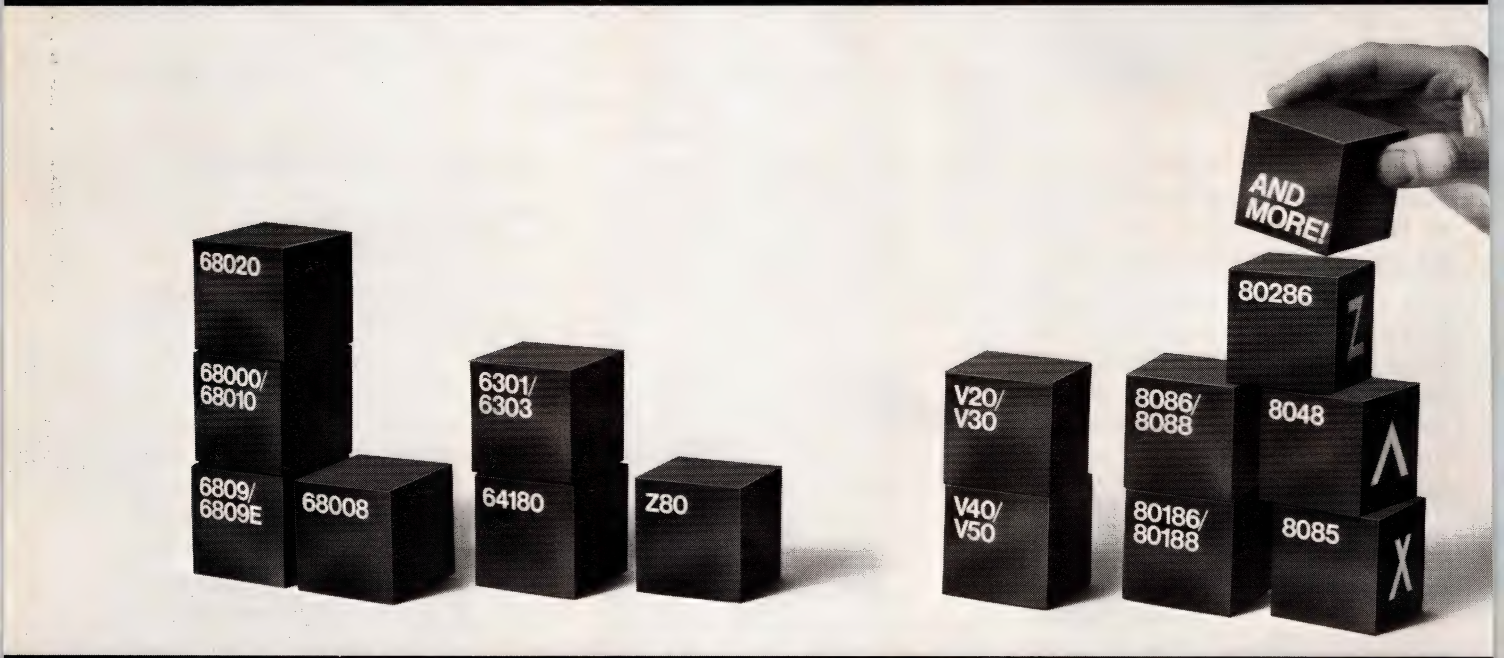

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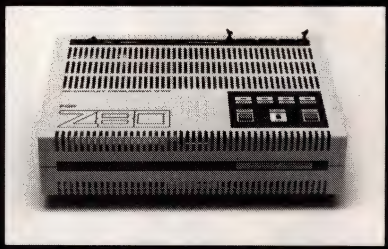
Simplify support for your microprocessor development projects with the help of ZAX! Call today to arrange a product demonstration or write for complete details about our product line. Call us TOLL FREE at 800-421-0982 (in California phone 800-233-9817) or write to ZAX CORPORATION, 2572 White Road, Irvine, CA 92714.

In Europe, call United Kingdom: 0628 476 741, West Germany: 02162-3798-0, France: (03) 956-8142, Italy: (02) 688-2141.



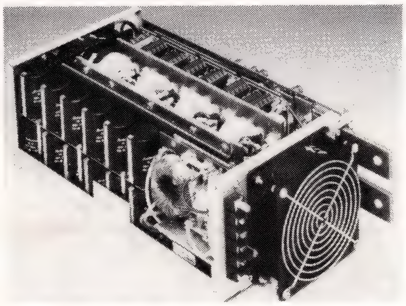
ZAX
Zax Corporation

CIRCLE NO 179

standard. An external TTL-compatible signal allows you to shut down power remotely. Each model includes an input filter to minimize reflected input ripple current. Continuous 6-sided shielding virtually eliminates radiated emissions. The devices operate over a −25 to +85°C temperature range. $219.

Power General, Box 189, Canton, MA 02021. Phone (617) 826-6216.

Circle No 384



POWER SUPPLIES

- *Feature 3 kW in a 5×8×15-in. package*
- *Operate on either ac or dc inputs*

Series 9R SuperSwitcher power supplies feature a 100-kHz switching frequency and provide 3000W output capability in a 5×8×15-in. package. Models in the series provide outputs of 2, 5, 12, 15, 24, 36, and 48V dc. AC input is nominally 220V single-phase (36A max) or 3-phase (21A max). The units can also function as dc/dc converters with a 200 to 375V input (19A max). Their standard features include current-sharing capability, active soft start, remote sensing, and automatic thermal shutdown. The devices' I/O signals include high- or low-logic inhibit, input-power fail, output good, remote adjust, current share, and margin low/high. The supplies are fan cooled and meet UL, CSA, IEC, and VDE specifications. 5V, 600A unit, $1890.

Powertec, 20550 Nordhoff St, Chatsworth, CA 91311. Phone (818) 882-0004.

Circle No 385

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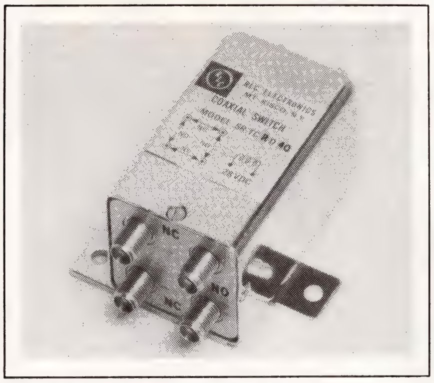
CIRCLE NO 180



TRANSFER SWITCH

- *Has dc to 40-GHz operating range*
- *Features 1-dB max insertion loss*

Model SR-TC-R-D-40 remote transfer switch operates over a dc to 40-GHz frequency range. The unit features a connector that will mate with either SMA- or K-type connectors. Maximum VSWR ranges from 1.3 (dc to 6 GHz) to 2 (26.5 to 40 GHz). For the same frequency bands, insertion loss equals 0.25 and 1 dB max and isolation measures 70 and 45 dB, respectively. The switch is available with a variety of options, including indicator circuitry, TTL control, a choice of power voltages, fail-safe or latching operation, and manual or remote control. From $525. Delivery, eight to ten weeks ARO.

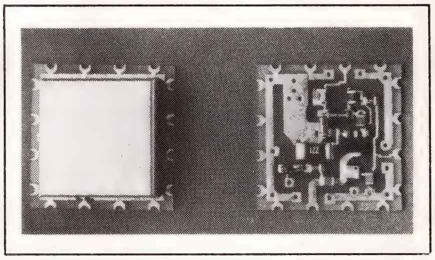
RLC Electronics Inc, 83 Radio Circle, Mount Kisco, NY 10549. Phone (914) 241-1334.

Circle No 386

OSCILLATOR

- *Features a 1-GHz tuning range*
- *Operates over a −40 to +85°C range*

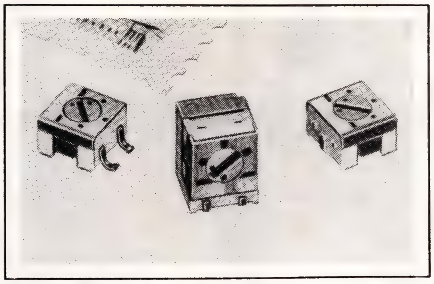
Model C-600SM is a surface-mount voltage controlled oscillator (VCO). The device's output varies from 1.3 to 2.3 GHz with tuning voltages of 2.5 to 30V dc. Its phase-noise char-



acteristics equal −78 dBc at 1-kHz offset and 1-Hz bandwidth (BW), −100 dBc at 10-kHz offset and 1-Hz BW, and −120 dBc at 25-MHz offset and 1-kHz BW. The unit requires 15V dc at 46 mA for normal operation; however, it will still output 0 dBm operating from 5V at 15 mA. The unit's output impedance measures 50Ω and its operating range equals −40 to +85°C. In an RF-shielded enclosure, $60. Delivery, six to eight weeks ARO.

Z-Communications Inc, 5450 NW 33rd Ave, Suite 100, Fort Lauderdale, FL 33309. Phone (305) 735-1000.

Circle No 387



POTENTIOMETERS

- *Compatible with automatic production techniques*
- *Designed for surface mounting*

G4 Series miniature surface-mount single-turn cermet potentiometers are suited for automated production techniques. They are available on tape and reel as standard packaging. The devices' design features a high-temperature construction (260°C for 10 sec) to accommodate flow and reflow soldering operations. Their resistance values range from 100Ω to 2M Ω. They feature a standard tolerance of ±20%, but ±10% is available for higher-valued units. All the devices have power ratings of 0.25W at 70°C and working voltages of 200V. The pots are sealed to accommodate board-cleaning operations, and are available in top-adjust configurations with J-hook, gull-wing, and pc-board type terminations. $1.47 (1000)

Tocas America Inc, 565 W Golf Rd, Arlington Heights, IL 60005. Phone (312) 364-7277.

Circle No 388

THERMOMETER

- *Has a 0.5-in. display*
- *Features 1° resolution*

The Oyster thermocouple (type K) thermometer features a 0.5-in. LCD built into an adjustable hinged cover. It has a lanyard neck strap and an on/off switch that automatically goes to the off position when the cover is closed. The unit weighs

12 oz and measures from −58 to +1999°F and −50 to +1350°C. Its resolution is 1°F or C, and its accuracy equals ±0.2% of reading ±1 digit. A kit is available that includes the meter, a general-purpose temperature probe, and a carrying case. The meter, $159; the kit, $219.

Extech Instruments Corp, 150 Bear Hill Rd, Waltham, MA 02154. Phone (617) 890-7440.

Circle No 389

Continued on pg 299

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Complete AC to DC and DC to DC multi output systems.

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Save Space: Completely protected AC-DC systems with rugged high density packaging to 8 watts/in^3.

Less Heat: Efficiencies to over 80% with next generation circuitry.

Higher Reliability: MTBF to 500,000 hours with conservative design criteria including NAVMAT guidelines.

MORE CHOICES

- Up to 8 DC outputs to 500 watts.
- 1ø, 3ø and DC inputs.
- –55°C to +85°C operation.
- Mil-Std-704A-D, 1399 and 1275 input surge and spike protection.
- Meets many provisions of Mil-Std-810D, Mil-E-5400 and Mil-E-16400.

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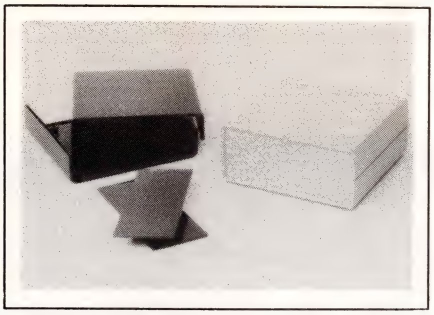
CIRCLE NO 182



ENCLOSURES

- *Carry a 94V-0 UL rating*
- *Feature optional EMI/RFI shielding*

This line of instrument enclosures includes three models. They measure 6-in. deep by 5.75-in. wide with front- and rear-panel heights of 2¼, 2⅝, and 3 in. The enclosures are made of 94V-0 ABS and are available in five colors. Front and rear panels are available in molded ABS or clear anodized satin-finish aluminum. The enclosures come in two packages—a prototype package that includes one enclosure complete with hardware and a bulk package that includes fifty enclosures. The devices' options include EMI/RFI shielding, pc-board mounting clips, plexiglass, and polarized front panels. Customized front and rear panels, including cutouts, silk screening, and engraving are also available. From $8.91.

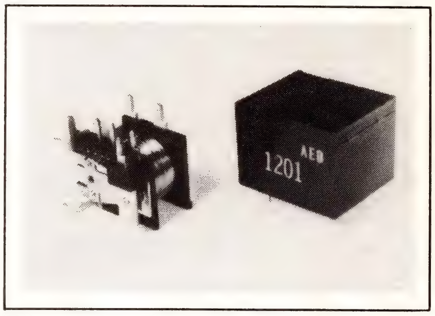
IEE Inc, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311.

Circle No 390

RELAY

- *Features 30A carrying capability*
- *Available in two contact configurations*

Designed for pc board mounting, Model PX can carry 30A load currents. Available in open or enclosed versions, the unit requires only 0.56 in^3 mounting space. The relays are currently available in 12 and 24V dc versions and offer a choice of spst and spdt contact configurations. All units are UL recognized and CSA approved. $1.34 (10,000) for open style versions. Delivery, stock to eight weeks ARO.



Global Components & Controls, One Main St, Suite 210, Eatontown, NJ 07724. Phone (201) 389-1470.

Circle No 391

NEW PRODUCTS

COMPUTERS & PERIPHERALS

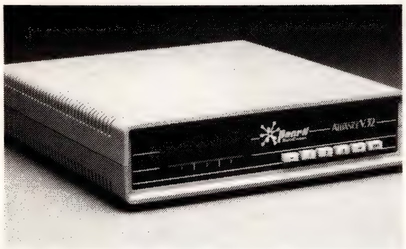
SCANNER

- *Digitizes 35-mm film for IBM PC and Macintosh II*
- *Resolution of 2000×2000 dots/in.*

The Scanmaster/35 scanner digitizes 35-mm film for display on an IBM PC or Macintosh II computer. The film can be in either positive or negative form, mounted or in strips. The unit uses a 2048-element CCD array, a fluorescent lamp, and a color wheel to digitize an image. An 8-bit IEEE-488 interface transmits the data for each scanned line. The unit has a scanning resolution of 2000×2000 dots/in., which results in an effective resolution of 1333×2000 dots/in. on a 35-mm image. In addition, it can rotate images 180 degrees. A menu-driven software package, Scan-It/35, lets you scan an image in black and white, select a subsection for sizing, and re-scan the newly sized image in full color. Hardware and software, $8195; hardware only, $6995.

Howtek Inc, 21 Park Ave, Hudson, NH 03051. Phone (603) 882-5200.

Circle No 405



V.32 MODEM

- *Can fall back to 4800, 2400, 1200, and 0 to 300 bps*
- *Asynchronous mode supports Microcom Networking Protocol*

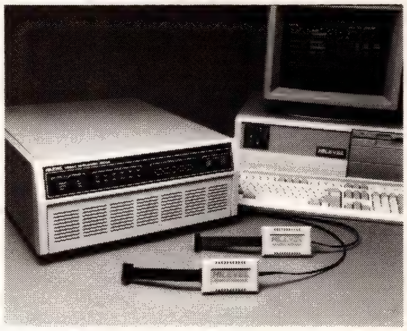
The Alliance V.32 modem operates asynchronously and synchronously. It provides full-duplex 9600-bps operation over the public-switched telephone network, and 2-wire and 4-wire leased lines. The unit can automatically fall back to 4800, 2400, 1200, and 0 to 300 bps operation; it complies with CCITT V.32, CCITT V.22bis, BELL 212A, and Bell 103 recommendations, respectively. In the asynchronous mode, the modem supports the Microcom Networking Protocol, Class 5 for error control. If the unit detects an error, MNP automatically requests retransmission of the affected data. In addition, MNP, Class 5 uses an adaptive data-compression algorithm to increase the data throughput as much as 200%. The unit supports the Hayes AT command set. $1595.

Penril DataComm, 207 Perry Parkway, Gaithersburg, MD 20877. Phone (301) 921-8600.

Circle No 406

DEVELOPMENT SYSTEM

- *System places an emulation module near the hardware*
- *Mainframe consists of 16 card slots*



The HiLevel DS5000 development system generates real-time software for VLSI processors and programmable ASICs; it features a design that places a module, which emulates memory, within 5 in. of the target hardware. The module, which eliminates the speed limitations of mainframe emulators, can be located as far as 7 ft away from the system chassis. The mainframe's 16 card slots accept either memory-module-interface cards or logic-analysis cards. The memory-module-interface cards communicate with as many as 4 memory modules; the logic-analysis cards can analyze as many as 16 channels, using multilevel triggering. The mainframe can process as many as 512 bits of memory emulation or 256 channels of logic analysis. A trace

mnemonic disassembler operates on the entire 256 channels for debugging parallel processors. From $10,000 to $20,000. Delivery, six weeks ARO.

HiLevel Technology Inc, 31 Technology Dr, Irvine, CA 92718. Phone (800) 445-3835; in CA (800) 541-2742. TLX 655316.

Circle No 407

PAGE PRINTER

- *Emulates the Diablo 630 printer for the single user*
- *Footprint measures 15.7×13.4×9.1 in.*

The CrystalPrint WP page printer for single-user word processing and business applications has a footprint that measures 15.7×13.4×9.1 in. Standard features include Diablo 630 emulation, 128k bytes of RAM, a parallel interface, 6-page/minute print speed, and 300×300-dot/in. resolution. Also included are ROM-resident and cartridge-based type fonts from Bitstream, one font cartridge slot, a removable paper tray, a 10,000-pg drum set, a 6000-pg toner set, and maintenance and warranty service. Two emulation options for the unit provide graphics capabilities, and HP LaserJet or Epson FX-85 dot-matrix printer emulation. $1299; emulation options, $79; memory-expansion option, increasing RAM to 256k bytes, $169.

Data Technology Corp, 2551 Walsh Ave, Santa Clara, CA 95051. Phone (408) 727-8899. TLX 4745044.

Circle No 408

DISK DRIVE

- *Boasts .02 msec access and data transfer at 40M bps*
- *Achieves speed by using RAM in front of a hard disk*

The Fastdisc is a memory device that utilizes RAM in front of a mechanical disk. The combination provides an access time of .02 msec and data transfers of 40M bps. You can start with a 15.8M byte system and expand it in 3.9M byte increments to 591M bytes. When the system is turned on all data on the mechanical disk drive is transferred to RAM. All accesses from the host computer

are to and from RAM. A transparent background routine constantly updates the mechanical disk. The unit will operate with any computer using the SCSI Interface per ANSI X3.131 standard. It provides automatic error detection & correction and has intelligent power backup. Systems with 15.8M to 27.7M bytes are housed in an enclosure which can sit on a desk or a floor stand; systems over 27.7M bytes are rack mounted. Prices start at $4875. 4M bytes of RAM, $1056 each. 16M-byte board, $6390.

Digital Electronic Systems Inc, 302 S Main St, Estill Springs, TN 37330. Phone (615) 649-5137.

Circle No 409

WORKSTATION

- *Emulates the IBM 3197C color-display station*
- *System/3X station provides 80- and 132-column operation*

The LynkStation/197C workstation emulates the IBM 3197C color-display station. It attaches to the IBM System/36, System/38, or 5294 remote-control unit as a 3197C or 3197D workstation. The unit has a 14-inch diagonal CRT display that offers eight colors and eight user-selectable palettes. The unit can display 80- and 132-character lines in full color. Tint and intensity may be adjusted in varying degrees. A dual-session feature allows the workstation to operate a single display station, two display stations, or as a display station and interface for

a system-addressable parallel printer. Most ASCII printers can be addressed as 5256 or 5224/25 printers. An optional plug-in cartridge drives an HP-compatible laser printer as an IBM 5219 printer. $1725.

The Lynk Corp, 101 Queens Dr, King of Prussia, PA 19406. Phone (215) 265-3550. TLX 4944315.

Circle No 410

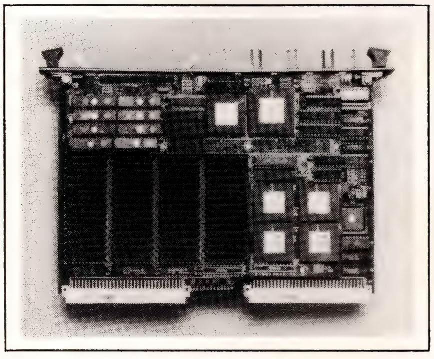
CONTROLLER

- *Interfaces VME Bus systems to IBM host computers*
- *Can perform a variety of control-unit emulations*

The SCHC10 VME Bus module allows you to interface a VME Bus system to IBM host computers via an IBM I/O channel interface. The double-Eurocard module, which occupies two VME Bus slots, operates as a control unit on the IBM channel and supports all three IBM channel types (selector, byte-multiplex, and block-multiplex). In addition to emulating a standard IBM control unit, an onboard 68010 µP and 512k bytes of RAM allow you to implement special-purpose control units by adding firmware to the board. The hardware supports three channel-transfer modes (standard interlock, high-speed interlock, and streaming), and allows data-transfer rates of 4.5M bytes/sec. An onboard 68450 4-channel DMA controller can transfer data directly between the IBM I/O channel and the VME bus, between the I/O channel and the local RAM, or between the VME Bus and the local RAM. In addition, FIFO buffers decouple the data flow to and from the I/O channel. Application support for several control-unit emulations is available from the company. DM 14,500.

Stollmann GmbH, Max-Brauer-Allee 81, 2000 Hamburg 50, West Germany. Phone (040) 3890030. FAX (040) 3809224.

Circle No 411



MEMORY MODULE

- *Drives 1280×1024-pixel displays*
- *VME Bus board acquires image data at 10M bytes/sec*

MaxView is a memory module for the company's VME Bus digital-processing and real-time image-processing boards. The board drives 1280×1024-pixel displays so you can view live on-screen windows with

"WE'VE GAINED MAXIMUM EXPOSURE WITH THE PRODUCT MART SECTIONS OF **EDN MAGAZINE** AND **EDN NEWS!**"

Cosette Trautman-Scheiber
Marketing Manager
SMT Plus, Inc.
San Jose, CA

Cosette Trautman-Scheiber is the marketing manager for SMT Plus, Inc., a two-year-old company that provides surface-mount designing, assembling, and education services.

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"I recommend EDN magazine and EDN NEWS. They are the right vehicles for getting our message to the market."

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EDN

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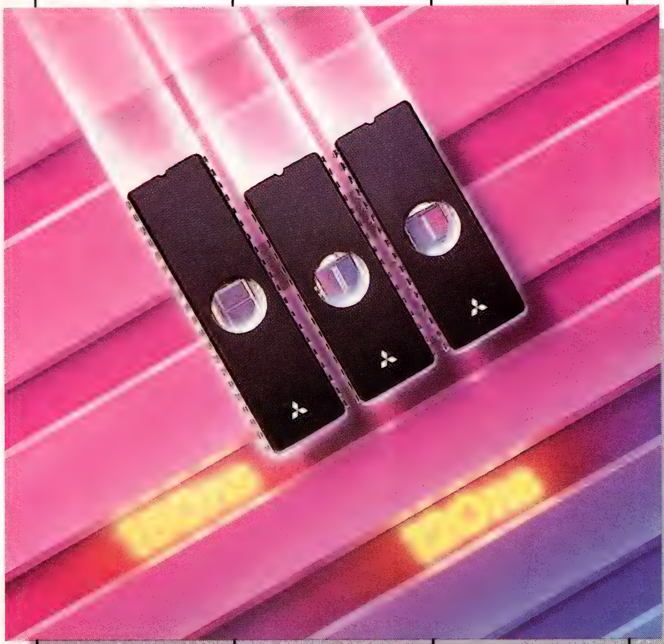


When You Want Fast 1 Mb EPROMs.

Mitsubishi delivers with a family of 150ns, CMOS 1 megabit UV EPROMs. Available now. And, for applications requiring even higher performance, 120ns versions are on the way.

Now, you can combine the advantages of fast access times and low power CMOS operation in the organizations and pin-outs you need.

There's a 128K x 8 that's pin-compatible with 1 Mb mask ROMs for easy conversion when you reach high volume production. Another device offers the JEDEC-standard pin-out allowing easy upgrade from lower density EPROMs. Plus, there's a 64K x 16, ideal for applications requiring wider data paths. And, they're all available in 150ns speeds. From Mitsubishi.

When You Want Cost-Effective Packaging Options.

If you want all the advantages of Mitsubishi EPROMs, but don't need to reprogram, Mitsubishi's 1Mb, 200ns CMOS OTP ROMs provide cost-effective alternatives for volume production.

And, for maximum flexibility, Mitsubishi's 1 Mb OTP ROMs are available in PDIP and PLCC packages, with SOP available soon.

For fast EPROMs, or cost-effective packaging options, call or write: Mitsubishi Electronics America, Inc., Semiconductor Division, 1050 East Arques Avenue, Sunnyvale, CA 94086. (408) 730-5900.

MITSUBISHI EPROMs

	Density	Organization	Part No.	Access Time (ns) 100	120	150	170	200	250	Package (CERDIP)
CMOS	128K	16K x 8	M5M27C128K			■		■	■	28 pin
	256K	32K x 8	M5M27C256K		■	■			■	28 pin
	512K	64K x 8	M5M27C512AK	■	■	■				28 pin
	1 Mb	128K x 8 64K x 16	M5M27C100K/M5M27C101K M5M27C102K			■ ■		■ ■	■ ■	32 pin 40 pin
NMOS	64K	8K x 8	M5L2764K					■	■	28 pin
	128K	16K x 8	M5L27128K					■	■	28 pin
	256K	32K x 8	M5L27256K					■	■	28 pin
	512K	64K x 8	M5L27512K				■	■	■	28 pin

MITSUBISHI OTP ROMs

	Density	Organization	Part No.	Access Time (ns) 200	250	Package Options
CMOS	256K	32K x 8	M5M27C256	■		28 pin PDIP and SOP
	1 Mb	128K x 8	M5M27C100	■		32 pin PDIP, PLCC and SOP
	1 Mb	128K x 8	M5M27C101	■		32 pin PDIP, PLCC and SOP
	1 Mb	64K x 16	M5M27C102	■		40 pin PDIP and 44 pin PLCC
NMOS	64K	8K x 8	M5M2764		■	28 pin PDIP
	128K	16K x 8	M5M27128		■	28 pin PDIP
	256K	32K x 8	M5M27256		■	28 pin PDIP and SOP
	512K	64K x 8	M5M27512		■	28 pin PDIP and SOP

Products subject to availability.

CIRCLE NO 185

Quality Through Commitment.

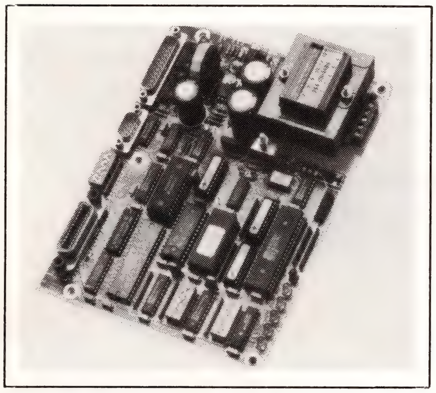
MITSUBISHI ELECTRONICS

Regional Offices:
NORTHWEST, Sunnyvale, CA (408) 730-5900
SOUTHWEST, Torrance, CA (213) 515-3993
SOUTH CENTRAL, Carrollton, TX (214) 484-1919
NORTHERN, Minnetonka, MN (612) 938-7779
NORTH CENTRAL, Mt. Prospect, IL (312) 298-9223
NEW ENGLAND, Woburn, MA (617) 938-1220
MID-ATLANTIC, Piscataway, NJ (201) 981-1001
SOUTH ATLANTIC, Norcross, GA (404) 662-0813
SOUTHEAST, Boca Raton, FL (305) 487-7747
CANADA, St. Laurent, Quebec, (514) 337-6046.

color graphic overlays on Sun and Apollo workstations. The board has a quad-ported 8-bit frame buffer arranged as 2048×1024 pixels with connections to the company's Maxbus. The Maxbus input port allows the board to acquire image data at 10M bytes/sec, while simultaneously the MAXbus output port transfers data at the same rate to other modules. The video output port lets the board's memory feed a MaxView D/A drive board at a 10-MHz rate to drive a display at speeds of 125 MHz max. Under $6500. Delivery, 90 days ARO.

Datacube Inc, 4 Dearborn Rd, Peabody, MA 01906. Phone (617) 535-6644.

Circle No 412



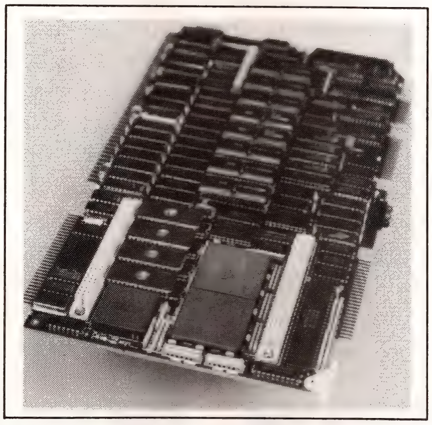
INTERFACE CARD

- *Connects devices with serial ports to IEEE-488 bus*
- *Provides RS-232C and RS-422 interfaces*

The Model 4814 IEEE-488 interface card for peripheral devices provides either an RS-232C or an RS-422 interface to the IEEE-488 bus. The card can act as both a talker and a listener interface for bidirectional communications. When it operates as a talker, you can add a character to the end of the message for compatibility—that is, you can convert CR (carriage return) to CR LF (carriage return-line feed) for HP computers. The card has a 3584-byte buffer for transmit and receive. Rocker switches select the baud rate (as high as 57.6k baud), character format, and bus address. The card contains an ac power supply, interface connectors, six LED indicators, and a reset button. The board measures 5.75×7.75×2.062 in. and weighs 1.6 lbs. Five ⅜-in. standoffs on the back of the card let you mount the card to a panel or chassis plate. $450.

ICS Electronics Corp, 2185 Old Oakland Rd, San Jose, CA 95131. Phone (408) 432-9009. TLX 286895.

Circle No 413



80386 BOARD

- *Achieves a data transfer rate of 32M bytes/sec*
- *CPU and bus dual-ported to 1M byte of static RAM*

The CP1-386/016 is an 80386-based CPU board for Multibus I. The board operates at 16 MHz and achieves bus transfer rates of 32M bytes/sec. An 82380 DMA controller provides 8 DMA channels, 15 interrupts, and 4 timers. Four sockets are available for as much as 1M byte of EPROM. Additionally, eight sockets are available for 1M byte of zero-wait-state static RAM. The static RAM is dual ported between the 80386 and Multibus I. You can expand the memory capacity by adding 1 or 2 memory-expansion modules. The modules are available in 1M-, 2M-, 4M-, or 8M-byte versions. The board has two serial channels that you can configure as either RS-232C or RS-422 ports. The board also has a SCSI and an iSBX interface. A socket is available

for an optional floating-point coprocessor. $3895.

Concurrent Technologies, 25401 Cabot Rd, Laguna Hills, CA 92653. Phone (714) 768-3332. TLX 989159 CONTECH USA.

Circle No 414

DMA BOARD

- *Provides DMA channels to the VME and VSB Buses*
- *Includes local memory for data processing*

The FIC8230 VME Bus board suits applications that require you to process data on-the-fly as it is transferred from one place to another. The board is based around a 68020 μP that is clocked at either 16 or 24 MHz, and a 68881 or 68882 math coprocessor. The board features an optional DMA controller, which can perform 16- or 32-bit block data transfers across the entire 4G-byte addressing range of the VME Bus. These DMA transfers can take place at data rates as high as 8M bytes/sec. The DMA controller can also transfer 32-bit data over the VSB Bus at data rates in excess of 10M bytes/sec. A third DMA channel allows you to transfer data to or from an 8-bit I/O port, which by adding external logic you can configure for a variety of uses—for example, as a SCSI port. The board has 512k bytes or 1M byte of zero-wait-state CMOS static RAM, which is ported to the 68020 and to the VME Bus, and ported to the VSB Bus via a DMA channel. The board also has 128k bytes of local RAM, and space for as much as 128k bytes of EPROM. Four independent 255×32-bit LIFO/FIF0 buffers provide the board with message-passing capabilities. Additional facilities include two RS-232C serial I/O ports, a 16-bit timer/counter, a real-time clock, and software-programmable board configuration. Between $4500 and $6000 depending on configuration.

Creative Electronic Systems SA, 70 route du Pont-Butin, 1213 Petit-Lancy 1, Switzerland. Phone (022) 925745. TLX 421320.

Circle No 415

C E Systems (US) Inc, 4655 Old Ironsides Drive, Suite 370, Santa Clara, CA 95054. Phone (408) 727-3360. Fax (408) 727-7721.

Circle No 416

BITBUS MODULE

- *Provides isolation and transient protection*
- *Protects networks operating in the 62.5k and 375k bps modes*

The iRCS 900 Isolation Module provides electrical isolation and transient protection for Bitbus networks. A dc/dc converter, optocouplers, and transient sup-

CIRCLE NO 49

THE ONLY THING FASTER THAN ROCKWELL'S MODEMS IS MARSHALL'S SERVICE.

At 14,400 bits-per-second, Rockwell's high-speed modems are a full generation ahead of the competition.

This new 14.4 Kbps modem family is the latest in Rockwell's leading R-series modems. The R144DP is the V.33/V.29 product offering which complements their R96DP and R48DP/208 high-speed modems. And the R144HD features are compatible to the R96F, the standard for facsimile modems.

Which is why Rockwell modems can be found in high-speed network controls and multiplexers, personal computers and terminals, custom modems, facsimile, and desktop publishing equipment around the world. In fact, Rockwell is the world's leading supplier of original equipment manufacturer modems.

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So if you need to communicate at rates up to 14,400 bits-per-second, and need to do it in a hurry, call Marshall today.

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Sacramento (916) 635-9700*
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KS Kansas City (913) 492-3121*
Wichita (316) 264-6333*
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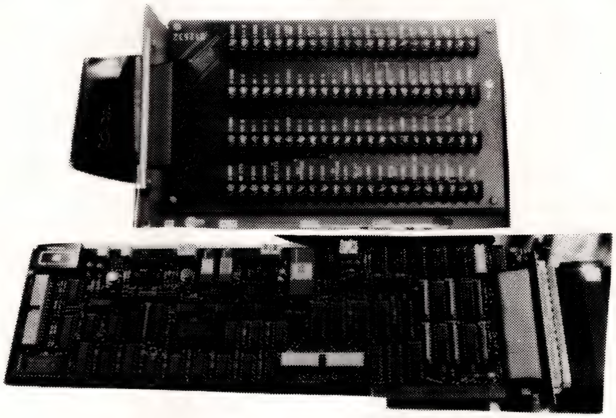
Mendelson Electronics Inc.

1-800-422-3525

CONTROL YOUR HOME OR BUSINESS FROM YOUR IBM*PC OR PC/AT COMPATIBLE

This card is what you need to TURN ON & OFF lights, machinery, and other electrical or electronic equipment.

IBM PC* DATA ACQUISITION AND CONTROL ADAPTER & DISTRIBUTION PANEL provides the capability to control and monitor processes within a sensor base system.



IBM PC*DATA ACQUISITION AND CONTROL ADAPTER provides an easy to use interface for accessing the ANALOG and DIGITAL I/O. Integrates analog, binary and time/counter devices on a single adapter card.

THIS IS AN ORIGINAL IBM* PRODUCT ! ! !

Up to four IBM DATA ACQUISITION AND CONTROL ADAPTERS can be attached to an individual PC or AT Compatible.

- The Adapter has:
  - Four analog input channels (12-bit resolution)
  - Two analog output channels (12-bit resolution)
  - 16-channel digital input port
  - 16-channel digital output port
  - Programmable sampling rates provided by a 32-bit timer
    - Event counter, programmable rate generator, or programmable time delay provided by a 16-bit user timer/counter

- The Distribution Panel has.
  - Screw terminals provided to attach devices to the distribution panel
  - Multiple grounds for twisted pair terminations
  - Shielded construction to minimize noise interference.

• USES

Chromatography, Electrochemistry, Energy management, Electronic testing, Process control, Data logging, Robotics.

Some parameters commonly monitored or controlled include: Pressure, Flow, Displacement, Voltage, Light intensity, Rotational speed.

Some instruments or devices that may utilize the Adapter are: Chromatographs, Spectrophotometers, Pressure gages, Relay controls, Thermocouples, Gas analyzers, Humidity sensors, Valve actuators, Level gauges, Load cells, Conductivity cells, ph Meters.

• TECHNICAL DATA

ANALOG INPUT: The analog input functions of the adapter operate in eigher programed or interrupting mode. The analog input functions provide 12-bit relative accuracy.

RESOLUTION - 12 bits

INPUT CHANNELS- four differential

INPUT MODES-	unipolar or bipolr, user-selectable
INPUT RANGES:	
unipolar	0 TO ±10 volts, user-selectable
bipolar	±5 and ±10 volts user-selectable
OUTPUT MODE:	
unipolar	straight binary
bipolar	offset binary
INPUT IMPEDANCE	>100 megohms with 100 picofarads
INPUT CURRENT	limited to less than ±4 mA
INPUT VOLTAGE:	
Normal mode	±30 volts maximum, without damage, power on or power off
Common mode	±11 volts maximum
COMMON MODE	
Rejection ratio	72 db
Integral linearity error	±1 LSB maximum
DIFFERENTIAL Linearity	
Error	± ½ LSB maximum
Stability	±5 ppm/degrees C of FSR (max)
GAIN:	
Error	±0.1% between ranges (max) any range adjustable to 0
Stability	±32 ppm/degrees C of FSR (max)
OFFSET:	
Error	adjustable to 0
Unipolar stability	±24 ppm/degrees C of FSR (max)
Bipolar stability	±24 ppm/degrees C of FSR (max)
MONOTONICIITY	0 to 50 degrees C
THROUGHPUT to memory	15,000 conversions/second min.

The analog output functions of the adapter operate in programed I/O mode. The analog output functions provide 12-bit relative accuracy.

RESOLUTION	12-bits
Number of output channels	2
OUTPUT modes	unipolar or bipolar, user-selectable
OUTPUT ranges:	
Unipolar	0 to ±10 volts, user-selectable
Bipolar	±5 and ± + 10 volts, user-selectable
INPUT CODE:	
Unipolar	straight binary
Bipolar	offset binary
OUTPUT Current	+5 milliamps, min. with normal loading and protection from damage with the output shorted to common.
OUTPUT Impedance	2 ohm, max.
CAPACITIVE loading	0.5 microfarads, max.
GAIN:	
Error	0.1 betweem ranges (max.). any range adjustable to 0
Stability	± ppm/degrees C of FSR(max)
OFFSET:	
Error unipolar	±3.25 millivolt max.
Error bipolar	adjustable to 0
Unipolar stability	±8 ppm/degrees C of FSR (max)
Bipolar stability	±24 ppm/degrees C or FSR (max)
MONOTONICITY	0 to 50 degrees C
SETTLING TIME	10 microseconds max. to within 0.1% FSR for a 10 volt step with 1000 of load
PROTECTION	Protected for short to common
OVERSHOOT	±1% of FSR max
THROUGHPUT from memory	25.000 conversion/second

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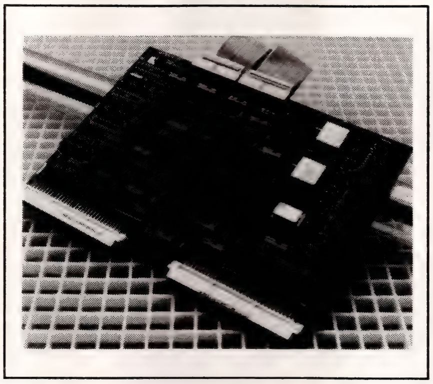
pressors protect networks operating in the 62.5k- and 375k-bps synchronous modes. The module provides protection against common-mode voltage as high as 1500V ac between nodes and transient voltage spikes as high as 2500V on the Bitbus interconnect. It can drive as many as 28 remote Bitbus nodes, allowing it to serve as an isolated stand-alone repeater. The module can be either panel-mounted or used on a desk top or a bench top. $367.

Intel Corp, Box 58065, Santa Clara, CA 95052. Phone (800) 548-4725.

Circle No 417

DSP BOARD

- *Delivers 10 MIPS for the Sun-3 workstation*
- *Has TI TMS32020 chips and a 16×16-bit multiplier*



The Sky Challenger-S digital-signal-processor board for the Sun-3 workstation utilizes two TI TMS32020 DSP chips and a 16×16-bit multiplier to multiply and accumulate in a single cycle at 10 MIPS. One of the DSP chips acts as a master to control the operational functions, and the other chip acts as a slave to perform arithmetic processing. This arrangement lets the host simultaneously move process integer data with no wait states. A multiported static RAM, with capacities ranging from 64k to 256k bytes, lets the VME Bus or both DSP chips access memory simultaneously. A 16-bit I/O interface lets you chain multiple boards together or connect to A/D converters. The board comes with a C compiler and cross-development tools to develop application code. $5200.

Sky Computers Inc, Foot of John St, Lowell, MA 01852. Phone (617) 454-6200.

Circle No 418

CPU CARD

- *Provides an 80386 processor for Multibus-I systems*
- *Includes 1M byte of zero-wait-state static RAM*

The CP1-386/016 CPU card for Multibus-I systems features a 16-MHz 80386 µP, and an 82380 8-channel 32-bit DMA controller. The board has eight sockets that support as much as 1M byte of zero-wait-state

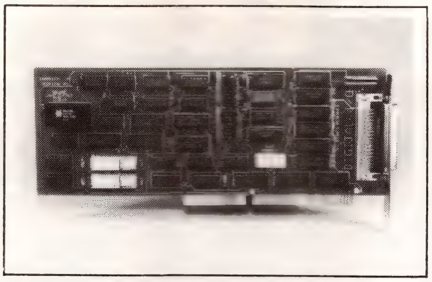
static RAM, and four sockets for as much as 1M byte of EPROM. The static RAM is dual-ported to the 80386 μP and to the board's Multibus-I interface. You can expand local memory by adding one or two memory-expansion modules, which are available with capacities of 1M, 2M, 4M, or 8M bytes. Additional onboard facilities include two RS-232C/RS-422 synchronous/asynchronous serial IO channels, a SCSI interface, an iSBX interface, and a socket for an optional 80387 math coprocessor. £2395.

Concurrent Technologies Ltd, Fairfax House, Causton Rd, Colchester, Essex CO1 1RJ, UK. Phone (0206) 42996. Fax (0206) 67333.

Circle No 419

Concurrent Technologies Inc, 25255 Cabot Rd, Suite 101, Laguna Hills, CA 92653. Phone (714) 768-3332. Fax (714) 951-8902.

Circle No 420



DIGITAL I/O

- *Features 16 lines of digital input*
- *Ruggedized board has 32 lines of digital output*

The Digital I/O Interface board for the IBM PC, AT and compatible computers has 16 TTL-compatible inputs configured as two 8-bit channels. Each line may be set to generate an interrupt on either a high or low level. Two 8-bit Delta Registers store status changes of each input line even for momentary-contact input sources. You can read data directly either from the inputs or from the Delta Registers. The board has 32 TTL-compatible outputs divided into four 8-bit channels. The outputs source 2.6 mA when high and sink 24 mA when low. An optional real-time clock is battery-backed for 10 years of operation without power. The board, designed for ruggedized operation, has a 50-pin D-shell connector that provides RFI and EMF shielding. $729. $42 for the optional clock.

Commtech Inc, Communication Technologies, 8622 Mt Vernon Ct, Wichita, KS 67207. Phone (316) 651-0077.

Circle No 421

PLOTTER

- *Accepts standard graphics-language commands*
- *Has a plot data buffer as large as 240k bytes*

The Colourwriter-6900 is an 8-pen A0 flatbed drafting plotter that con-

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Mizar presents the perfect addition to a great line of real-time target processors: a great real-time development environment. First, choose from Mizar's array of real-time servers that include an enclosure fully integrated with VME processors, peripherals, and Wind River Systems' VxWorks™ Real-Time Operating System. Plug the server into your Sun network and you're ready to develop, download, and test your application code.

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MIZAR

1419 Dunn Drive • Carrollton, TX 75006 • (214) 446-2664 **CIRCLE NO 189**

nects via RS-232C or IEEE-488 interfaces to micro, mini or mainframe computers. Accepting HPGL standard graphics-language instructions, the plotter is compatible with a wide range of CAE packages including Autocad, Prodesign, Generic CADD, Orcad, and Racal Redboard. It features a standard data buffer capacity of 64k bytes that you can optionally expand to 240k bytes, and it includes character generators for a variety of character sets. The plotter has a writing speed that is programmable in steps of 0.3 cm/sec to 40 cm/sec max, and a pen-positioning speed with the pen raised to 55 cm/sec. It uses electrostatic paper hold down, and industry standard pen types. The plotter's pen-positioning resolution is 0.025 mm, and it has a single-pen repeatability of ±0.05 mm. Its overall dimensions are 1580×1100×195 mm, and to minimize the required installation space you can wall-mount the plotter so that it lies flat against the wall. Around £6000.

Advance Bryans Instruments Ltd, 14/16 Wates Way, Mitcham, Surrey CR4 4HR, UK. Phone 01-640 5624. TLX 946097.

Circle No 422

3D GRAPHICS

- *Has effective resolution of 4864×4096 pixels*
- *Add-on to the VAX 8000 workstation*

When coupled with an adapted PS 390 terminal, the Stereo Option for the VAXstation provides stereo viewing of 3D models. The monitor has two liquid crystal modulators, which alternately switch on and off in 1/98 sec, to produce left- and right-handed circularly polarized light. The user wears passive viewing glasses with left- and right-handed circular polarized filters covering the left and right eye, respectively. The glasses, which look like ordinary eye glasses, let more than one person at a time view the model. A line-smoothing operation, called antialiasing, produces an effective resolution of 8196×6912 pixels in monochrome. During stereo operation the resolution reduces to 4864×4096 pixels. The product sells as an $11,500 option for the VAX8000 workstation.

StereoGraphics Corp, Box 2309, San Rafael, CA 94912. Phone (415) 459-4500. TWX 650-231-9225.

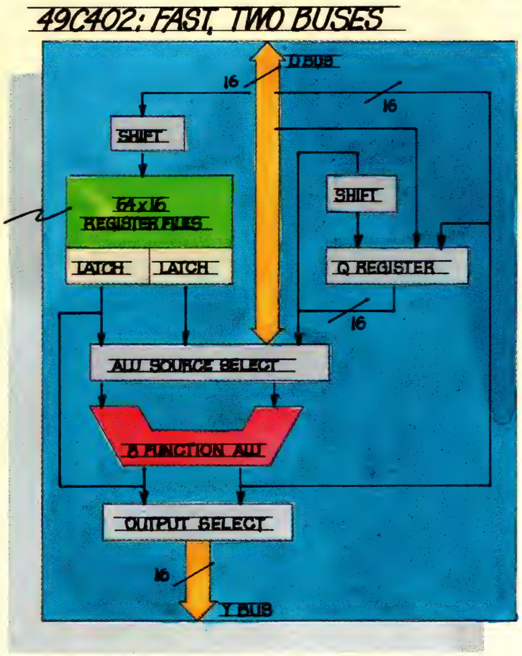
Circle No 423

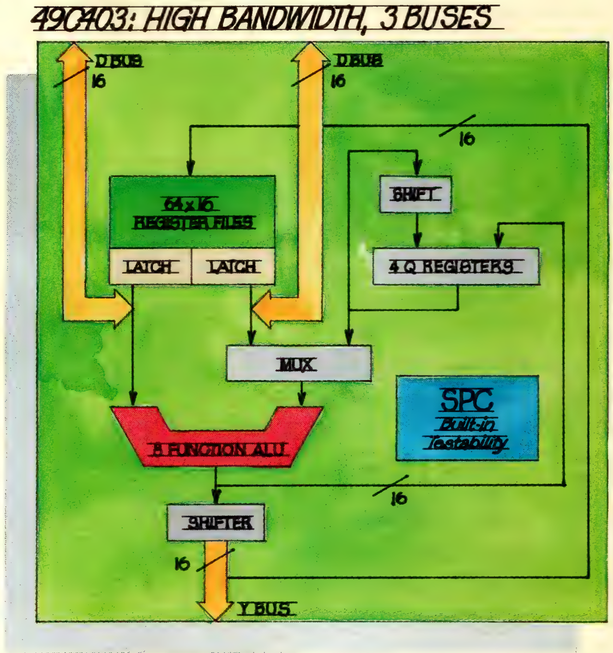
CPU BOARD

- *Uses a 25-MHz 68020 CPU for the VME Bus*
- *Contains 1M byte of dual-port, zero-wait-state RAM*

The V07 CPU board for the VME Bus uses a 25-MHz 68020 CPU. It

The Ultimate 16-bit slice...





It's your choice!

If you need speed, choose the CMOS 2-bus IDT49C402

- Two-bus 2901-type architecture
- Fastest: 37ns RAM address to output
- 10ns set-up—Direct D-bus to RAM and Q
- Independent RAM & Q shifts

64 deep register file. Provides you with more on-chip working space for your high-speed multi-tasking algorithms.

Eight new destination functions. New operands now can be brought into the register file during ALU operations; ideal for address generation.

Now in plastic packages. Low-cost, compact, 68-pin plastic pin grid array and surface mount PLCC.

Upgrade your existing 2901 design. 2901 instruction set compatible so it is easy to upgrade. □ Higher performance: 50% faster than 2901C. □ Reduced board space: 68 pins vs. 176 pins (5 parts). □ Lower power dissipation: 1 watt vs. >5 watts (bipolar).

If you need flexiblility and high bandwidth, choose the CMOS 3-bus IDT49C403.

- Three-bus 2903-type architecture
- Fast: 50ns RAM address to output delay
- Expandable register file
- Byte as well as word operations
- SPC™ diagnostics logic

Expandable register file. Can be expanded to provide even more working space for complex digital signal processing algorithms.

Three-bus architecture. For high bus bandwidth. Can perform high-speed integer functions while fixed/floating point multipliers perform the matrix calculations. Ideal for graphics.

On-chip SPC diagnostics. Provides on-chip diagnostic support for design debug, production board level test and field diagnostics.

Upgrade your existing 2903/203 system. 2903/203 instruction set compatible. Performs BCD arithmetic and word and byte operations. □ Better performance — 40% faster than 2903A. □ Reduced board space —108 pins vs. 208 pins (5 parts). □ Lower power dissipation — 1 watt vs. >5 watts bipolar.

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NEW Writable Control Store RAM—*for microprogram memory*—71502, 4Kx16 Registered RAM

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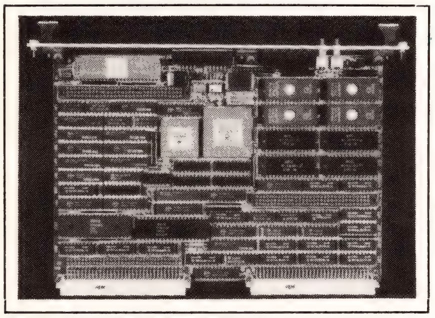
Fastest 4-bit slices—39C01/03/203 = 2901/03/203 □ 39C09/11 = 2909/11

Call **408-492-8314** for your free copy of our new 1800 page, 1988 high-performance CMOS DATA BOOK. Or call your local IDT representative.

Integrated Device Technology
3236 Scott Blvd.
Santa Clara, CA 95054-3090
(408) 492-8314
FAX: 408 727-2328

contains a 68881 coprocessor and 1M byte of dual-port, zero-wait-state RAM. A Bus Master Boot feature lets you boot a multiple CPU system from one boot PROM. This feature also frees up a socket for 512k bytes of additional RAM per board. Another feature, which contributes to a multiple-CPU environment, dynamically allocates interrupt-handling functions between processors on the VME Bus. The board also contains a Z8536 programmable controller and a 68155 bus-interrupt manager. The baseboard has two serial ports, which you can configure as RS-232C, RS-422, and RS-485 ports. $1995.



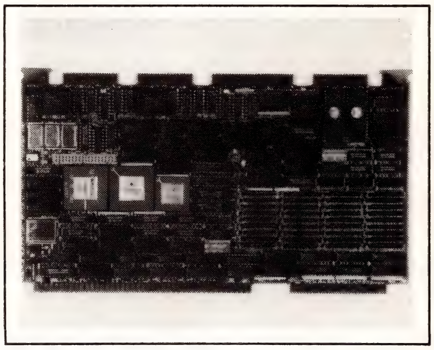
General Micro System Inc, 4740 Brooks St, Montclair, CA 91763. Phone (714) 625-5475.

Circle No 424

MULTIBUS I SBC

- *Based on a 25-MHz 68030 CPU and runs Unix System V.3*
- *Contains 1 or 4M bytes of dynamic RAM with parity*

The HK68/M130, a single-board computer for Multibus I, contains a 25-MHz 68030 CPU, 1 or 4M bytes of onboard dynamic RAM with parity, as many as 2M bytes of EPROM, and a 4-channel, 32-bit DMA. In addition, the board includes a SCSI interface, 4 RS-232C I/O ports, a 16-bit parallel port, an 8-bit iSBX connector, 128 bytes of nonvolatile RAM, 3 16-bit counter/timers, iLBX memory expansion, mailbox



interrupt support, and a full master/slave interface to Multibus I. Optional features include a 68881 or 68882 floating-point coprocessor, and a time-of-day clock with battery backup. The board runs on Unix System V.3, Ready Systems' VRTX real-time executive, and Microware's OS-9 operating system. 4M-byte dynamic RAM version, $4995.

Heurikon Corp, 3201 Latham Dr, Madison, WI 53713. Phone (800) 356-9602; in WI, (608) 271-8700. TLX 469532.

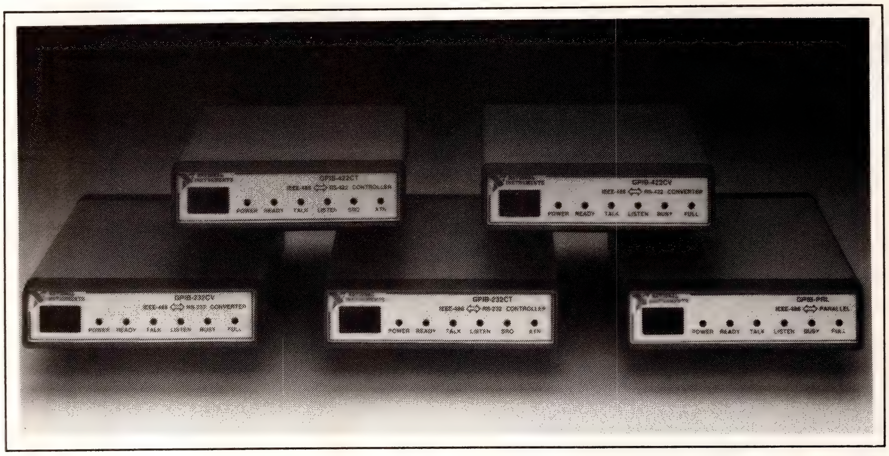
Circle No 435

NEW PRODUCTS

TEST & MEASUREMENT INSTRUMENTS

BUS CONTROLLERS

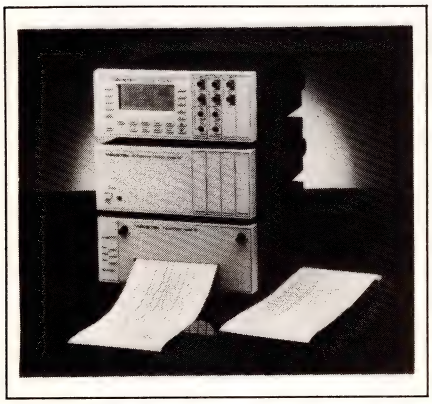
- *Control bus from host's RS-232C or RS-422 port*
- *Include 64k- or 256k-byte RAM buffers*



The GPIB-232CT and GPIB-422CT bus controllers let you control an IEEE-488 bus from any computer that has an RS-232C port or an RS-422 port. The units contain 64k bytes, or optionally, 256k bytes of RAM to buffer data returned from the IEEE bus devices to the host. The units accept data at speeds as high as 900k bytes/sec and support serial-port data rates from 300 to 38,400 bps. Each bus controller has its own µP and DMA controller. The bus controllers incorporate a firmware-resident, bus-control language and operating system that enable you to control the IEEE-488 bus from any computer's serial port without using special software. The units can act as normal or extended talkers and listeners. They support serial and parallel polling, service and pass/receive-control requests, and can be remotely programmed in three modes. With 64k-byte RAM buffer, $595; with 256k-byte RAM buffer, $795.

National Instruments Corp, 12109 Technology Blvd, Austin, TX 78727. Phone (800) 531-4742; in TX, (800) 433-3488. TLX 756737.

Circle No 395



DATA-LOGGING SYSTEM

- *Stores >100k readings in internal RAM*
- *Linearizes output of seven thermocouple types*

The Model 52A data logger combined with the Model 53 expansion chassis, and, optionally, with the Model 54 alphanumeric/graphics printer accommodates as many as 260 analog inputs. Its internal, battery-backed RAM can store as many as 100,000 readings. The linearization routines handle seven thermocouple types. The cold-junction compensation is automatic. You can program 99 alarms and average as many as 65,536 readings to minimize the effect of noise. You use "channel lists" to tell the data logger what to do with acquired information. The channel lists can have 254 entries and can repeat 254× within a scan. From $4000. Delivery, four to six weeks ARO.

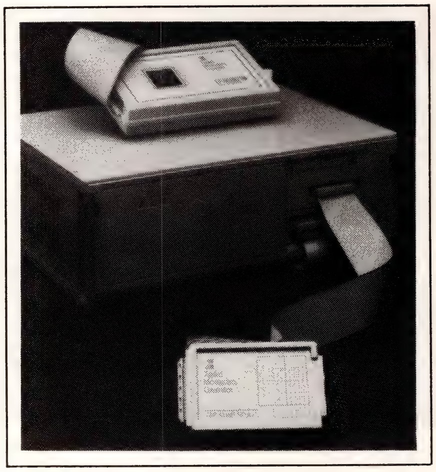
Wavetek, 9045 Balboa Ave, San Diego, CA 92123. Phone (619) 279-2200. TWX 910-335-2007.

Circle No 396

TIME-STAMP MODULE

- *Monitors events and elapsed time*
- *Measures program, memory, and module-linkage activity*

The time-stamp module connects to the vendor's ES 1800 family of in-circuit emulators for Intel, Motorola, and Zilog 16-bit µPs. It permits real-time, nonintrusive measurement of software performance. The

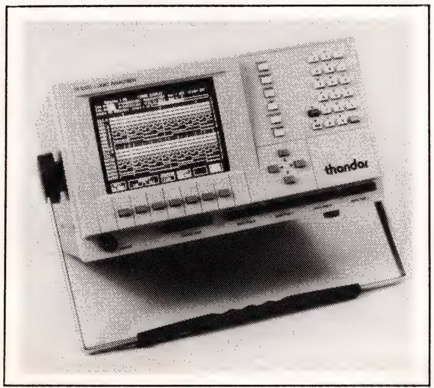


timing and counting modes permit eight types of measurements. You can measure the amount of time a program spends within a software module, outside of the module, or between modules. This information can help you determine where to focus your code-optimization effort. When you measure program, memory, or module-linkage activity, the unit counts the number of occurrences of a defined event. You can use a Sun or Apollo workstation, a DEC VAX, or an IBM PC or com-

patible computer as the emulators' host processor. The supported µPs include the 8086/88, 80C86/88, 80186/188, 80286, 68000, 68008, 68010, Z8001, and Z8002. $1200.

Applied Microsystems Corp, Box 97002, Redmond, WA 98073. Phone (800) 426-3925; in WA, (206) 882-2000. TLX 185196.

Circle No 397



LOGIC ANALYZER

- *Provides 32-channel, 25-MHz data capture*
- *Features multilevel triggering*

The TA1000 logic analyzer provides 32 25-MHz state/timing channels. It features a 1k-bit/channel trace memory and provides external clock facilities that include three independent clock inputs and five clock qualifiers. You can define as many as four 32-bit trigger/restart words, which you can OR together in each step of a 4-step trigger sequencer. Each step of the trigger sequencer also includes a 1 to 256 event counter. You can display timing or variable-format state information on the analyzer's 7-in. CRT, and can analyze it using the instrument's trace-expansion facilities, two screen cursors, and reference memory. The instrument can also perform automatic trace/reference memory comparisons on the traced data, optionally stopping trace acquisition on trace/reference equality or inequality, or counting the occurrences of these conditions. The instrument includes IEEE-488, RS-232C, and Centronics interfaces, and a nonvol-

Who's got the button?

Nobody, but nobody, offers or delivers more rechargeable button cells and batteries than Varta.

The first in NiCd batteries.

This year, 1988, Varta celebrates its 100th year in manufacturing batteries of all types. In the '50's we led the world in commercialization of NiCd batteries.

100 years 1888 1988 VARTA

We invented the mass-plate cell construction which excels over sintered nickel-cadmium cells.

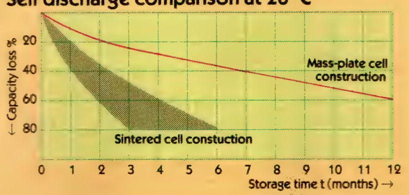
Unique performance advantages.

In stand-by at ambient temperatures, our mass-plate button cells retain 60% capacity after 12 months versus about three months for sintered NiCd cells, because they have much lower internal losses. Similarly, they require much lower recharging rates, as low as 1mA (C/100) versus 4-7mA for competition, so charging power and circuitry will be minimized.

More compact designs.

Varta mass-plate button cells and batteries usually take much less space—or let you put up to 40% more capacity in the same space.

Self discharge comparison at 20°C



Better shelf life.

Cells can be stored in any state of charge for over five years without significant loss of performance.

Cost benefits, too.

With all their advantages, Varta mass-plate button cells and batteries usually cost less than comparable sintered-type cells.

Many sizes and types.

Capacities range from 4 mAh to 1000 mAh. Many flat or stacked batteries can be assembled. Extra high temperature ratings and UL listings are available in key sizes. For rechargeable applications above 1000 mAh, Varta also offers a complete line of NiCd cells and batteries.

For an introduction to Varta's world-leading line of rechargeable button cells and batteries, please ask for "Who's Got The Button". Call 1-800-431-2504, Ext. 260, or write below.

VARTA

VARTA Batterie AG, Am Leineufer 51, D-3000 Hannover 21, West Germany, Tel. (49) 0511/79031
VARTA Batteries, Inc., 300 Executive Blvd., Elmsford, NY 10523, USA, Tel. 1-800-431-2504, Ext. 260
VARTA Batteries Pte Ltd., 1646 Bedok North P.O. Box 55, Singapore 9146, Tel. (65) 241-2633

CIRCLE NO 191

atile memory for captured data, reference data, and 16 instrument setups. You can obtain disassemblers for a variety of 8- and 16-bit μPs as options. With TTL-threshold input pods, £1790; with variable threshold pods, £2250.

Thandar Electronics Ltd, London Rd, St Ives, Huntingdon, Cambridgeshire PE17 4HJ, UK. Phone (0480) 64646. TLX 32250.

Circle No 398

WAVEFORM RECORDER

- *Samples at 10 MHz*
- *Includes ring buffer expandable to 2M samples*

The styling and footprint of the SDA2000 transient-waveform recorder's enclosure mimic those of an IBM PC/XT's. The unit, which can offer from one to eight channels, communicates with the host via an IEEE-488 interface. Sampling can occur at rates as high as 10 MHz. A ring buffer that can hold 1M samples is standard; you can expand it to hold 2M samples. The A/D converter resolves 12 bits. Programmable-gain amplifiers with 3-MHz bandwidth and programmable offset of 4× full scale precede the converter and provide 31 calibrated full-scale ranges from 50 mV to 80V. You can trigger the unit with a TTL trigger command or from a signal being digitized. Trigger-signal conditioning facilities include lowpass filtering. Software for the host computer converts data to engineering units, performs many computations, and provides easily interpreted displays. $9995.

Soltec Corp, Sol Vista Park, San Fernando, CA 91340. Phone (800) 423-2344; in CA, (818) 365-0800.

Circle No 399

LCR METER

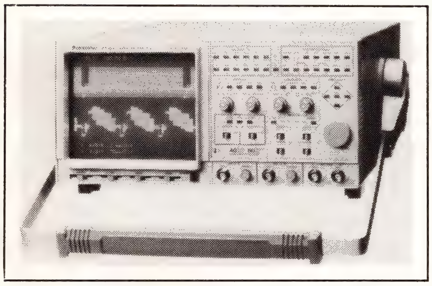
- *Measures on 22 ranges at two frequencies*
- *Operates for 40 hours from 9V alkaline battery*

You can obtain the handheld LM22A in the standard battery-powered version or in an optional ac-powered version. It uses a 3½-digit LCD to display inductance from 19 μH to 199.9H in seven ranges, capacitance from 19 pF to 1999 μF in eight

ranges, and resistance from 1Ω to 19.99 MΩ in seven ranges. On most ranges, the unit measures inductance and capacitance with an accuracy of ±(1%+1 digit), resistance with an accuracy of ±(0.5%+1 digit), and dissipation with an accuracy of ±(1%+2 digits). The inputs are protected against damage caused by overvoltage. The display features an overrange indication. You can order a carrying case as an option. Including test leads, manual, and spare fuse, $199.

Beckman Industrial Corp, 3883 Ruffin Rd, San Diego, CA 92123. Phone (619) 495-3224.

Circle No 400



A/D SCOPE

- *Captures 15-MHz one-shot and 100-MHz repeated waveforms*
- *Displays 8k 8-bit samples*

The VP-5720A A/D storage scope samples at 40 MHz. When engaged in equivalent-time sampling, it can handle repetitive signals that contain frequencies to 100 MHz; with single-shot phenomena, its bandwidth is 15 MHz. The unit digitizes with 8-bit resolution and displays 8k samples. It also operates in an X-Y mode, in which it displays with 8-bit precision along each axis. You can move the trigger window along the horizontal axis to reveal pretrigger and posttrigger conditions. To reduce the effect of random noise, the unit can average two to 256 samples. It displays the number of samples averaged on its 7-in. CRT. $6000.

Panasonic Industrial Co, 2 Panasonic Way, Secaucus, NJ 07094. Phone (201) 392-4050.

Circle No 401

NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

LISP/dBASE LINK

- *Provides Lisp functions that simulate dBase III commands*
- *Lets Lisp programmers apply AI methods to dBase III*

dBLisp is a set of 50 GCLisp functions and keywords that simulate the commands that define and manipulate dBase III files. These functions allow Lisp applications to create, manage, and retrieve dBase III file information. The package lets Lisp application programs apply AI (artificial intelligence) techniques to the problems of accessing and managing a dBase III database. Lisp application programs on which you can use the program include expert-system inference mechanisms, natural-language interfaces to the database, and other interactive front ends. To use dBLisp, you'll need the vendor's Golden Common Lisp; you won't immediately need dBase III, however, because dBLisp writes and stores dBase-compatible data, index, and memo files. dBLisp, $295; with source code, $495.

Chestnut Software Inc, 636 Beacon St, Boston, MA 02215. Phone (617) 262-0914. TLX 516840.

Circle No 425

SYMBOLIC DEBUGGER

- *Lets an IBM PC or compatible execute 68020 software*
- *Provides single stepping and breakpoints*

The Sim 20 cross debugger allows you to test and debug your 68020 software on an IBM PC or compatible. The package, which simulates all 68020 functions, includes Load, Dump, and Breakpoint facilities, and lets you single step through a program or execute it at full speed. When the program reaches a breakpoint or after it has completed a step, you can display the effects of the current instruction on flags, registers, and 68020 memory. You can also disassemble and display hex files of Motorola S-records. To use the debugger, you need a machine with at least 256k bytes of RAM that runs under DOS version 2.0 or later. $385.

Big Bang Software Inc, Beachwalk Centre, 7151 W Hwy 98, Suite 286, Panama City Beach, FL 32407. Phone (904) 784-7114. TWX 910-250-1687.

Circle No 426

CAE DATA MANAGER

- *Uses relational database technology to provide security*
- *Provides release/revision control*

Product Data Manager, previously available only for the vendor's CAE workstations and for Prime computers, is now available for VAX/VMS systems. The data manager lets you control all aspects of a CAE/CAD/CAM database. It employs relational-database technology to offer three management facilities: a controlled-storage feature that provides tools for database access and security; a data-distribution feature that supplies tools for storing, retrieving, and moving collections of data elements; and a data-management feature that offers a release/revision-control system, an administration module, and a customizable programming interface. From $75,000.

Computervision Corp, 100 Crosby Dr, Bedford, MA 01730. Phone (617) 275-1800.

Circle No 427

80386 TOOLS

- *HLL compilers provide global optimization*
- *Support Intel 80387 and Weitek 1167 coprocessors*

The Oasys 80386 software-development tool kit consists of Green Hills C, Pascal, and Fortran compilers, and complementary assembler/linker options. For development on an IBM PC or an 80386-based ma-

chine, you should select the Phar Lap (Cambridge, MA) assembler and the LinkLoc linker/locator, available from the vendor or from Phar Lap. LinkLoc lets you generate ROMable code for downloading to the target machine in Intel hex, Intel 32-bit hex, S-records, OMF386, and the Phar Lap proprietary formats. The tool-kit options include the vendor's Designer C++ preprocessor and Fortran and C source-level debuggers. If you are cross-developing on a Unix machine, such as a Sun, Apollo, or VAX workstation, you should select the vendor's Avalon MX386 assembler and Avalon LX386 COFF linker, which produces standard Unix output in COFF format in an a.out file. All of the compilers support the Intel 80387 and Weitek 1167 math coprocessors and have interlanguage calling facilities—for example, C programs may call Fortran or Pascal subroutines. Compilers, $795 to $3000; Phar Lap assembler/linker combination, $495 to $1400; Avalon assembler/linker combination, $1500 to $3000.

Oasys, 230 Second Ave, Waltham, MA 02154. Phone (617) 890-7889.

Circle No 428

PICTURE DATABASE

- *Captures, stores, and indexes graphics on an IBM PS/2*
- *Works with a variety of image-capture boards*

PicturePower employs the extensive graphics features of the IBM PS/2 and compatibles in picture-database applications. The software lets you select and use 256 colors from the PS/2's palette of 256,000, includes an internal database manager, and is compatible with Ashton-Tate's dBASE III Plus. You can imbue existing dBASE applications with pictorial capability or incorporate such capability in new ones. Employing a video camera and an image-capture/display board, you can create databases containing signatures, photographs, and documents, for use with applications that require visual identification of the data. Until August 1988, purchasers of the software will receive a free image-capture board. $995.

PictureWare Inc, 111 N Presidential Blvd, Bala Cynwyd, PA 19004. (215) 667-0880.

Circle No 429

FILTER DESIGN TOOL

- *Analyzes filter design and selects component values*
- *Provides Bode plot and compares result to ideal response*

PMSS Active Filter Design Tools 2.0 is a low-cost, filter-analysis and -design program that covers the most commonly used filter designs. The program handles 1 Hz to 50 kHz filters of one to six poles. You can use it for Butterworth, Chebyshev, Bessel, and elliptic filters with highpass, lowpass, or bandpass response. You specify the transfer function, and the program selects appropriate component values. It then prints a Bode plot of the response predicated on the use of these values, together with a plot of the ideal response of the specified transfer function. You'll need an IBM PC or compatible that has at least 384k bytes of RAM; a CGA, EGA, VGA or compatible graphics card; and an Epson-compatible printer. $55.

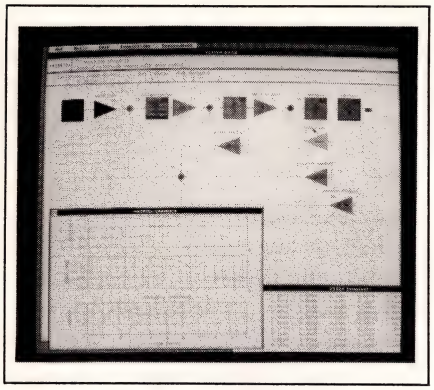
Power Mountain Software Systems, Box 6, Dept M, Cora, WY 82925.

Circle No 430

CAE OPTIMIZATION

- *Provides block-diagram modeling and simulation*
- *Speeds up solutions to problems that require iteration*

The $Matrix_x$ optimization module lets you specify a design problem using system-analysis commands and graphical, function-level simula-



tion models. A command then translates the specification into a mathematical optimization problem. The program solves the problem with the aid of an enhanced version of the Kalmarkar algorithm. The program determines the values of design variables that optimize the performance index that you have specified, solves simultaneous equations, and determines whether your design can meet the specifications. The tuning factors for all algorithms feature carefully selected default values, eliminating guesswork. You can request that intermediate results be displayed or plotted as the algorithm proceeds. You can obtain the program in versions for VAX computers and Apollo workstations. Apollo version, from $4000.

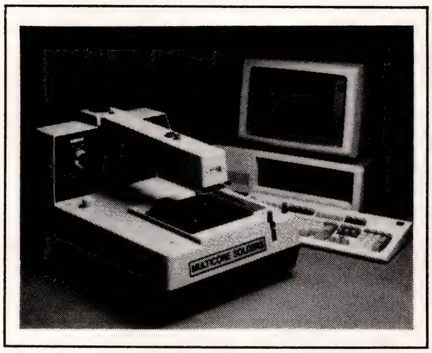
Integrated Systems Inc, 2500 Mission College Blvd, Santa Clara, CA 95054. Phone (408) 985-1500.

Circle No 431

SOLDER TESTING

- *Lets IBM PC control vendor's solderability tester*
- *Can test solderability of SMT devices and compare test runs*

The MustMate 100/110 and the MustMate 200/210 software packages provide a means of controlling the vendor's multicore universal solderability tester (Must) and analyzing the test results. You can store the test conditions for each compo-



nent type; when you recall them via a code number, the program sets the Must controls and reads in the evaluation parameters. At the end of a test run, you can display any number of force/time curves and use the stored evaluation parameters to assess the solderability of the component leads. MustMate 100 and 110 each guide you through the steps necessary to perform a wetting balance test on leaded components in accordance with DIN 32 506, MIL-STD-883C, and IPC-S-805 standards. MustMate 200 and 210 each

provide the same facilities and, in conjunction with the vendor's SMT kit, let you test the solderability of surface-mount devices. Each program occupies approximately 80k bytes of memory and stores the results on floppy disks; a 360k-byte disk holds approximately 200 results if the test immersion time is 10 seconds; you can store more results by reducing the test immersion time to 5 seconds. MustMate 100 and 200 run only on IBM PC/ATs and compatibles, whereas MustMate 110 and 210 can run on IBM PC/XTs and compatibles. All four versions require that your machine have a Hercules graphics card and the CEC PC-488-IEE GPIB interface card. MustMate 100/110 or 200/210, $2495 each.

Multicore Solders, Cantiague Rock Rd, Westbury, NY 11590. Phone (516) 334-7997.

Circle No 432

AUTOROUTER

- *Runs on IBM PC/ATs under DOS or OS/2*
- *Works in conjunction with your schematic-capture software*

The MaxRoute add-on autorouting program can work with any schematic-capture package that runs on 286- and 386-based machines. The program comes with one translator that permits data transfers between the autorouter and your particular CAD system; you can obtain translators for use with other systems at an extra charge. The program includes a shove feature and performs sweep routing and multipass heuristics. The interactive steering feature optimizes routing paths through congested board areas. The program operates in either an automatic or semiautomatic mode, and it features a batch mode that allows several designs to run in sequence or a single design to run under different technologies or strategies. To ensure completion of the routing, the program examines a small routing window down to the half-grid level; when the program identifies the optimal half-grid space in which to route a line, it shoves aside blocking lines or vias and routes on this ideal path. According to the vendor, the program takes approximately eight hours to achieve 100% routing of a 200-equivalent-IC board, with a density of 0.4. To run the program, you need an IBM PC/AT or compatible, or an 80386-based machine, with at least 640k bytes of RAM, a hard disk or network file server, a mouse or other pointing device, and a color-graphics card and monitor compatible with IBM's MCGA, EGA, or VGA. $6500; additional translators, $500 each.

Massteck, Box 1128, Littleton, MA 01460. Phone (617) 486-0197.

Circle No 433

C CROSS COMPILER

- *Runs on IBM PCs and compatibles and VAX/VMS machines*
- *Generates code for MC68HC11 microcontroller*

Version 3.3 of the vendor's C cross compiler now runs on IBM PCs and compatibles and on VAX machines under VMS. The package includes CXDB/6811, a new interactive, source-level cross debugger. The compiler can use any one of five programming models to optimize the code either for speed or compactness. The compiler passes source-line-number information and the name, type, storage class, and address of program data to the object file for use by CXDB/6811 or by another debugging tool, such as an in-circuit emulator. License fees for the C cross compiler, $1500 to $7000, depending on the host; license fees for both the cross compiler and cross debugger, $2500 to $12,000.

Whitesmiths Ltd, 59 Power Rd, Westford, MA 01886. Phone (617) 692-7800. TLX 750246.

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TLX-561	640 × 200	1/200	0.35 × 0.49	275 × 126 × 14	Yes	T7779
TLX-711A*	240 × 64	1/64	0.53 × 0.53	180 × 65 × 12	Yes	T6963C**
TLX-341AK*	128 × 128	1/64	0.45 × 0.45	93.2 × 86.6 × 12	No	T6963C

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CIRCLE NO 194

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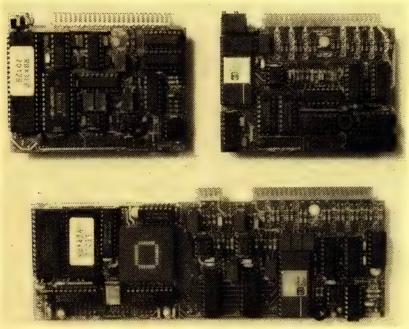

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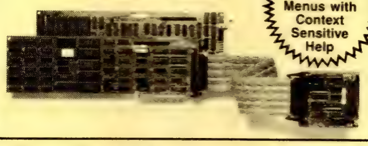

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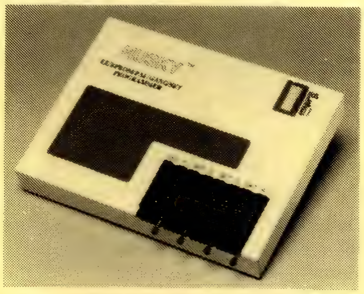

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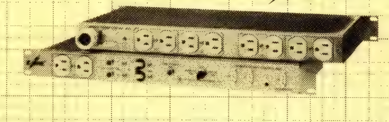

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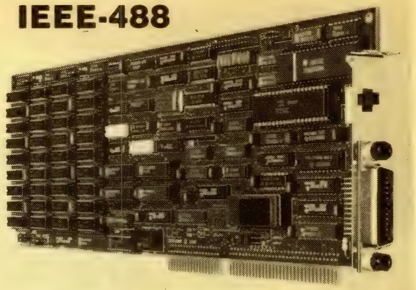

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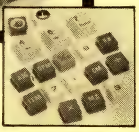

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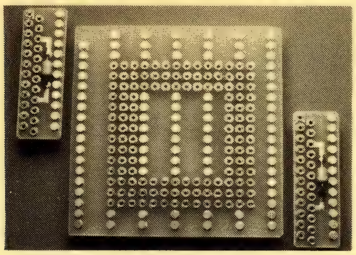

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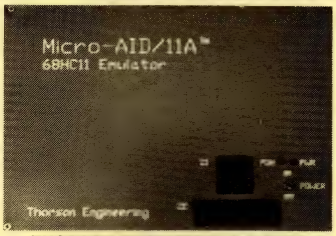

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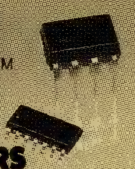

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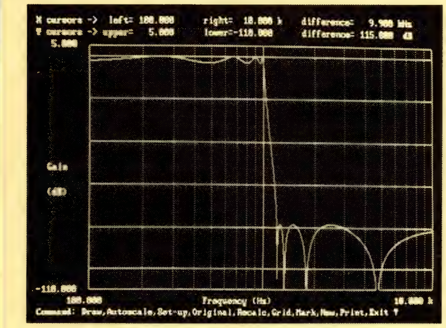

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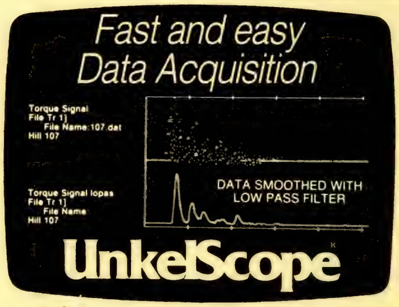

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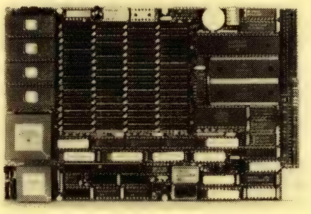

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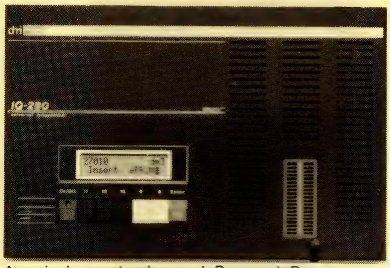

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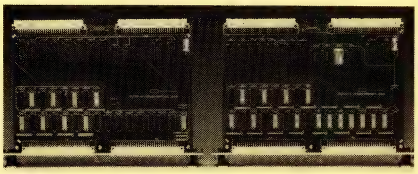

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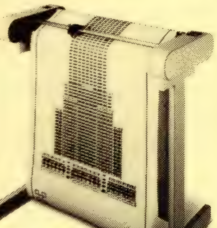

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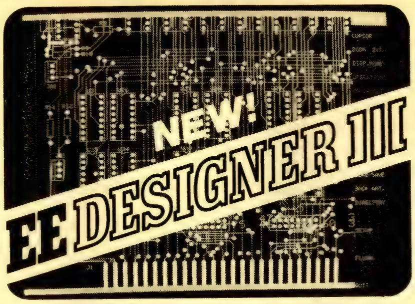

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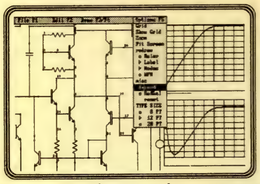

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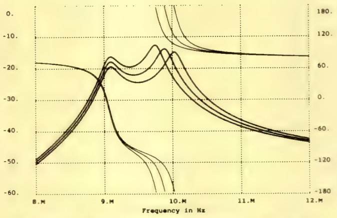

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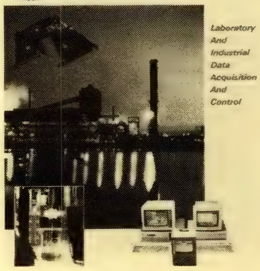

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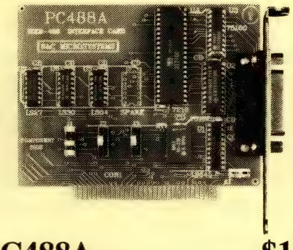

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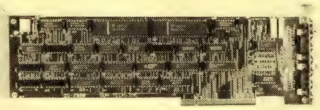

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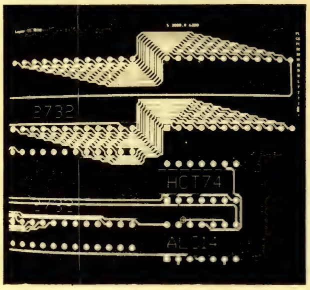

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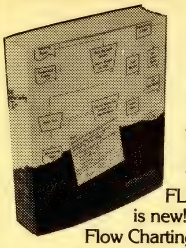

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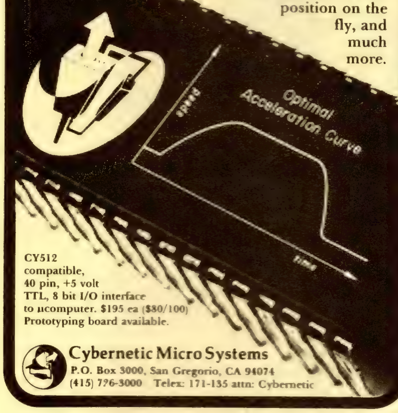

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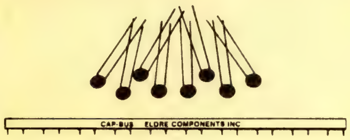

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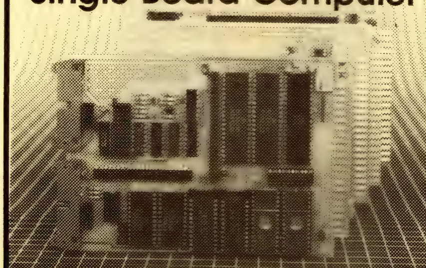

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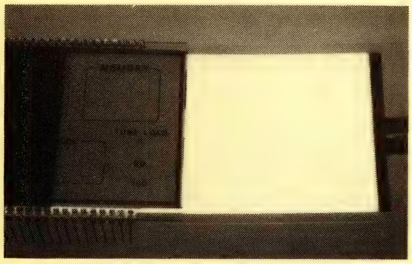

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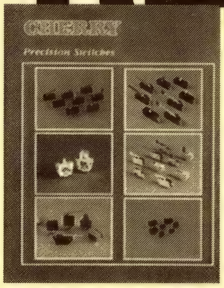

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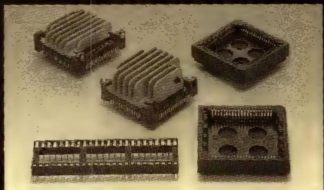

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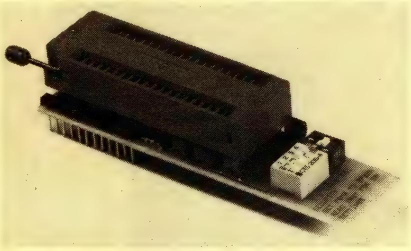

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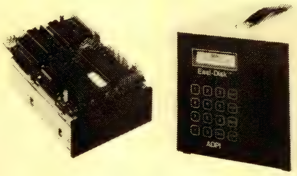

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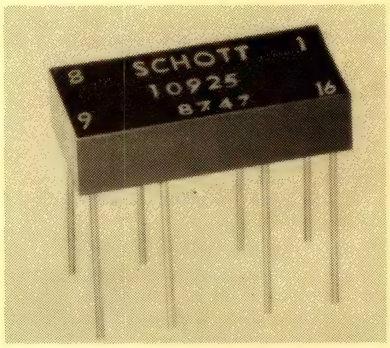

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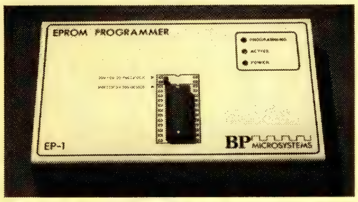

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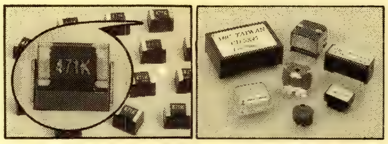

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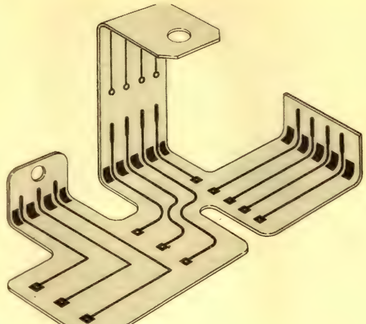

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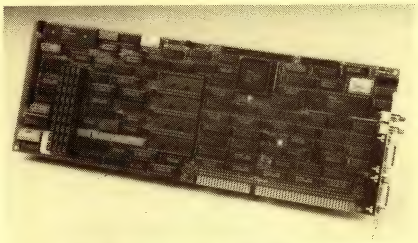

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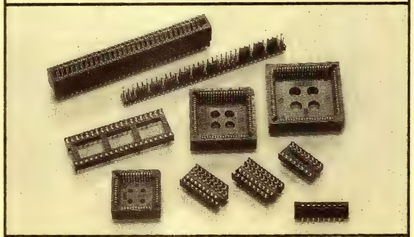

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EDN Product Mart

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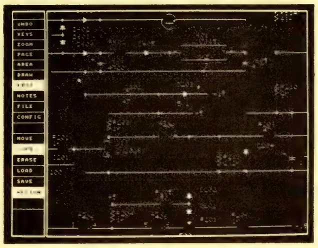

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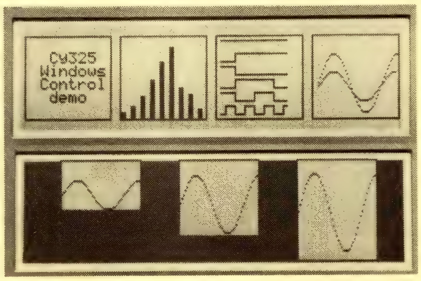

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CIRCLE NO 793

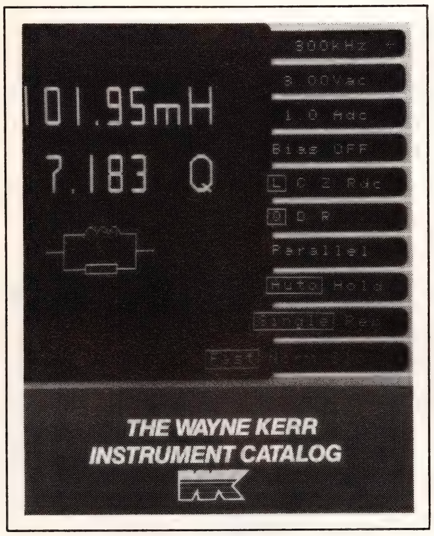
To advertise in Product Mart, call Joanne Dorian, 212/463-6415

Reference series covers Transputer

The *Transputer Reference Manual* describes Transputer architecture and the Occam model, as well as four Transputer models: the 32-bit T800 with an on-chip floating-point coprocessor, the 32-bit T414, the 16-bit T212, and the M212 peripheral-controller Transputer. It also discuses the C004 communications link switch, and the C011 and C012 communications link adapters. The remaining five books to be published in 1988 are entitled *Transputer Instruction Set: A Compiler Writer's Guide; Transputer Development System; Digital Signal Processing in Inmos Devices; Communicating Process Architecture;* and *Transputer Technical Notes*. The *Transputer Reference Manual* is available now for $34.95; the other volumes in the series will range in price from $34.95 to $42.95.

Prentice Hall, Prentice Hall Building, Englewood Cliffs, NJ 07632.

INQUIRE DIRECT

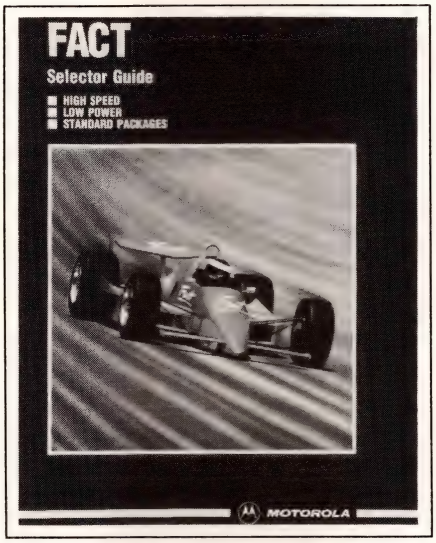


Instruments cataloged

The vendor's 28-pg catalog presents three precision analyzers and seven LCR (inductance-capacitance-resistance) meters. It provides explanations and illustrations of product features and specifications for each product. The Selection Guide helps you select the instrument you need. The Terms and Techniques section focuses on the terminology and methods used in testing capacitors, resistors, and inductors.

Wayne Kerr Inc, 600 W Cummings Park, Woburn, MA 01801.

Circle No 441



Guide helps you select logic ICs

The vendor's 8-pg *Fact Selector Guide* describes Fact CMOS logic ICs and provides information about CMOS logic surface-mount technology. Besides its chart of logic family comparisons that allow you to compare and select standard logic elements, a CMOS numeric listing presents the devices scheduled for the second quarter of 1988.

Motorola Inc, Literature Distribution Center, Box 20912, Phoenix, AZ 85036.

Circle No 442

Quarterly review emphasizes Unix tradition

Based on systems influenced by Unix, *Computing Systems*, a quarterly journal of the Usenix Association, concentrates on the analysis and understanding of the theory, design, art, engineering, and implementation of advanced computer systems. It deals specifically with operating systems, architecture,

networking, programming languages, and advanced applications. Nonmember US subscription, $40; single copy, $10.

Computing Systems, University of California Press, 2120 Berkeley Way, Berkeley, CA 94720.

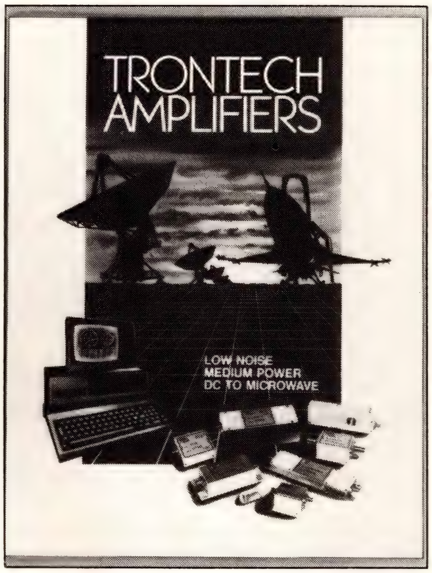
INQUIRE DIRECT

Brochure sums up PC-to-mainframe transfers

This 6-pg publication *Mag Tape Power For Your PC* presents three different approaches to processing bulk data transfers between PCs and mainframe computers. It includes software solutions for DOS and Xenix, based on PC systems. It also describes Filetran for selective file-based backup, as well as hardware solutions, using three different tape systems.

Telebyte Technology Inc, 270 E Pulaski Rd, Greenlawn, NY 11740.

Circle No 444



Pamphlet depicts dc-to-microwave amplifiers

The vendor's 12-pg brochure offers information about low-noise, medium-power, dc-to-microwave amplifiers. Out of almost 1500 available models, the publication lists approximately 400 of the most popular amplifiers. The listing includes the following types of amplifiers: silicon and GaAs FET low-noise; medium- and high-power RF and microwave; and ultra-wide-band low-noise and medium-power. It also mentions the company's optional custom production and variations for standard amplifiers. General information, definitions of commonly used technical terms, graphs, charts, and mechanical dimensions of standard case styles complete the brochure.

Trontech Inc, 63 Shark River Rd, Neptune, NJ 07753.

Circle No 445

App note expounds upon signal-source capability

Application Note 358-1 *Characterization of Frequency-Agile Signal Sources* investigates the HP 5371A frequency and time-interval analyzer's ability to analyze frequency-hopping signals and other capabilities. The publication discusses switching-transient analysis, settling-time verification, and the analysis of FM or FSK modulation. It also explains mixer down-conversion and prescaling to extend the analyzer's range to RF and microwave frequencies.

Hewlett-Packard Co, Customer Information Center, Inquiry Fulfillment Dept, 19310 Pruneridge Ave, Cupertino, CA 95014.

Circle No 446

Publication features backplanes

This 8-pg, 4-color brochure describes the vendor's sole product and service, custom pressfit backplanes for wire-wrap, card-cage as-

sembly, or hand-soldering capabilities. It includes specifications, diagrams, and photographs.

Qualtech Backplane Inc, 16682 Milliken Ave, Irvine, CA 92714.

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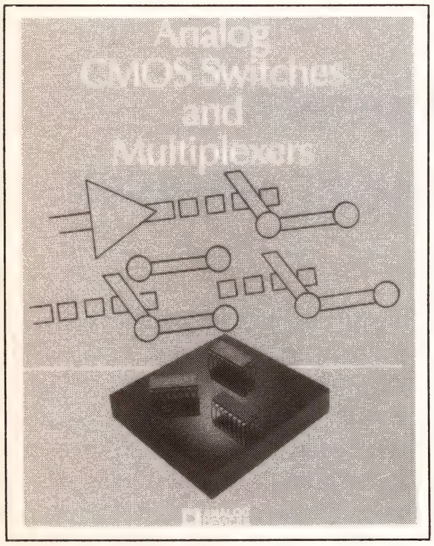

CMOS switches and multiplexers cataloged

The company's 16-pg catalog *Analog CMOS Switches and Multiplexers* contains a listing of products, block diagrams, and reliability data. The publication also features a section on single-supply operation.

Analog Devices, Literature Center, 70 Shawmut Rd, Canton, MA 02021.

Circle No 448

Software products categorized

This 56-pg catalog summarizes information about the vendor's data-acquisition and control equipment for IBM and Apple computers. It introduces LT/Control and Genesis, factory-controlled software for the IBM PC and Analog Connection Chrom for the Macintosh II and SE. The publication also contains a price list, as well as a listing of sales representatives.

Strawberry Tree Computers Inc, 160 S Wolfe Rd, Sunnyvale, CA 94086.

Circle No 449

Programming language manual

The *occam 2 Reference Manual* serves as a reference text for the high-level Occam programming language or as an introduction to the language for anyone who has a reasonable understanding of programming languages. The 132-pg paperback volume presents the language from its most elementary processes to actual procedures and functions. The manual is designed for computer scientists, software engineers and programmers, electronics engineers, and system designers.

Inmos Corp, Box 16000, Colorado Springs, CO 80935.

Circle No 450

Leaflet discusses spectrum analyzer

This 8-pg brochure features the Model 2383/2380 spectrum analyzer and display. Besides general information about the device, the publication discusses IEEE-488 bus capabilities, markers, horizontal scales, receiver modes, vertical scales, and display and storage. It also describes the digital method of signal processing with limit masks, self-calibration, and plotting functions.

Marconi Instruments, 3 Pearl Ct, Allendale, NJ 07401.

Circle No 451

What do college kids know? Students name their top employer choices

Deborah Asbrand, *Associate Editor*

When it comes to that first job out of college, some things never change. Graduating electrical engineers' top choices for employment are the perennial favorites IBM, Hewlett-Packard, AT&T, and General Electric. What has changed, however, is the way in which students go about deciding which companies they'd most like to work for. Whereas company representatives, open houses, and brochures once held sway over students, college seniors now say that they base their opinions on media reports and on their own experiences with a company's products.

With minor variations, electrical-engineering students have voted the same companies among their top choices since *Graduating Engineer* magazine began conducting the survey in 1981. The poll asks students to name their three top choices for postgraduate employment. It includes students from all engineering backgrounds, but electrical-engineering students make up the largest contingent at 25%. The survey was conducted in 1987, and the results released in April.

Texas Instruments and Hughes took the number six and number seven slots, respectively, while Lockheed and Rockwell tied for the number eight position. Semiconductor companies returned to favor with students in the 1987 poll. Motorola ranked ninth, a respectable rebound from its 1985 position, number 17. Intel, too, made the top 10, tieing with Boeing for tenth place. In contrast, students responding to the 1985 survey had showed little interest in Intel, with just 1.5% indicating the company as their first choice for employment. Last year, perhaps influenced by the positive publicity surrounding the 80386 chip's release, 7% of the students put Intel at the top of their lists.

Indeed, the power of the press is becoming more evident in students' selections. Digital Equipment Corp tied for seventeenth place in the 1985 survey. Since then, however, the company has introduced a variety of new products and established itself as a strong competitor for IBM. The press has covered DEC's turnaround in detail, and the company's successes have not been lost on students: In the 1987 survey, DEC shot up to fourth place.

In addition to media reports, students respond to the more subtle messages in advertising. After Burroughs and Sperry merged to become Unisys, the new company embarked on an ambitious publicity campaign to promote not just the new name but the marriage of the two companies. Students got the point. They showed little confusion and readily began using the new name in their lists of choices.

Not so for RCA, which General Electric bought in 1986. In contrast to the marriagelike demeanor of the principals in the Burroughs-Sperry merger, General Electric has done little to preserve or refresh RCA's identity since its purchase of the company. As a result, RCA's standing has plummeted with students. It has dropped from the number 12 spot in the 1983 poll to number 26 in 1987, with just 1.1% of students reporting the company as their first choice.

Two upstarts breaking into the top 25 for the first time are Apple Computer and Microsoft, both of which have enjoyed tremendous success over the past two years. Apple's appearance may attest to the Macintosh II's growing reputation as an engineering tool. Wang Laboratories' fortunes, on the other hand, illustrate how quickly reputations can be gained and lost. Whereas Wang scored high with students in both the 1981 and 1983 polls, it was nowhere to be found in last year's survey.

Shifting influence

Although the influence of corporate representatives on students remains marked—43% mentioned it as factor in their decisions—it is on the wane, as is the impact of company brochures. Instead, students demonstrate a distinct preference for avenues of information over which companies have little control. Fifty-

three percent of students say that they base their opinions partially on newspaper or magazine articles, which is 11% more than indicated so in 1983. One third of the students also rely on the advice of family members and friends. And almost half of the respondents cite their experiences with a company's products as influencing their employment preferences.

Among the factors affecting students' choices are the locations of the schools that they attend. Students favor companies with facilities near their colleges or universities. Electrical-engineering majors in New England, for example, would most like to work for Massachusetts-based DEC, whereas their counterparts in the Mid-Atlantic states choose IBM first and General Electric second, two companies strongly represented in New York.

The survey also noted the increasing number of foreign students enrolled in engineering programs. Questions regarding students' ethnic backgrounds were optional, and 28% of the respondents chose not to answer them. Of those who did report their ethnic background, 19% identified themselves as Asian, up from 13% in 1983. **EDN**

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WHERE DO STUDENTS WANT TO WORK?
THE TOP 20

	1987	1985	1983
IBM	1	1	1
HEWLETT-PACKARD	2	2	2
AT&T	3	#	6
DIGITAL EQUIPMENT CORP.	4	17	6
GENERAL ELECTRIC	5	3	3
TEXAS INSTRUMENTS	6	6	4
HUGHES	7	4	5
LOCKHEED	8	12	15
ROCKWELL		7	7
MOTOROLA	9	17	7
BOEING	10	11	19
INTEL		25	15
GENERAL MOTORS	11	16	16
GENERAL DYNAMICS	12	18	14
NASA		13	17
MARTIN MARIETTA	13	17	20
McDONNELL DOUGLAS		19	9
TRW	14	14	11
HARRIS	15	10	8
HONEYWELL		9	7
NORTHROP		21	21
GTE	16	15	10
FORD	17	21	17
EASTMAN KODAK	18	10	19
NCR	19	24	21
NATIONAL SECURITY AGENCY		27	#
NORTHERN TELECOM		#	#
BELL COMMUNICATIONS RESEARCH	20	20	#

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(*SOURCE:* GRADUATING ENGINEER *MAGAZINE AND DEUTSCH, SHEA, AND EVANS*)

Elizabeth Stubbs

CAREER OPPORTUNITIES

1988 Editorial Calendar and Planning Guide

EDN

Issue Date	Recruitment Deadline	Editorial Emphasis	EDN News
July 7	June 14	Product Showcase—Vol. I, Power Sources, Software	Closing: June 23
July 21	June 30	Product Showcase—Vol. II, CAE, Test & Measurement	Mailing: July 14
Aug. 4	July 14	Sensors & Transducers, Analog ICs, Graphics	Closing: July 21
Aug. 18	July 28	Military Electronics Special Issue, Displays, Military ICs	Mailing: Aug. 11
Sept. 1	Aug. 11	Instruments, Op Amps, Computers & Peripherals	
Sept. 15	Aug. 25	Data Acquisition, Data Communications, Digital ICs	Closing: Sept. 1
Sept. 29	Sept. 8	DSP, Graphics, Optoelectronics	Mailing: Sept. 22
Oct. 13	Sept. 22	Test & Measurement Special Issue, Instruments, Computers & Peripherals	Closing: Sept. 29
Oct. 27	Oct. 6	CAE, Computers & Peripherals, Integrated Circuits, Wescon '88 Show Preview	Mailing: Oct. 20
Nov. 10	Oct. 20	Programmable Logic Devices, Integrated Circuits, Test & Measurements, Wescon '88 Show Issue	Closing: Oct. 27
Nov. 24	Nov. 3	Microprocessor Technology Directory Graphics, CAE	Mailing: Nov. 17

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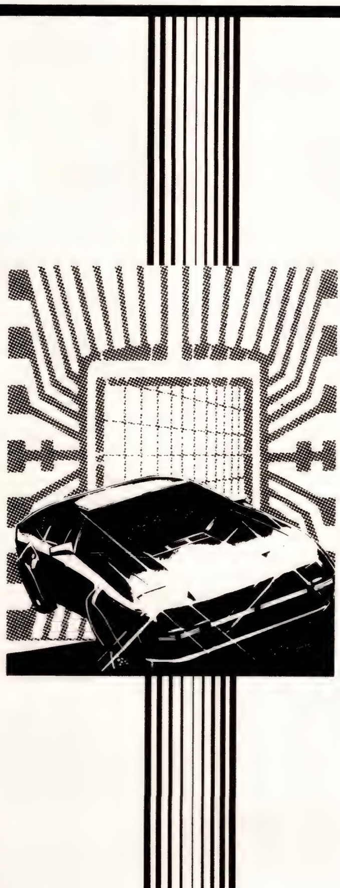

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- Will generate PDL from detailed design documents, coding of programs in CMS2 and Assembly language and unit testing of the programs. Requires 3-8 years' software experience.

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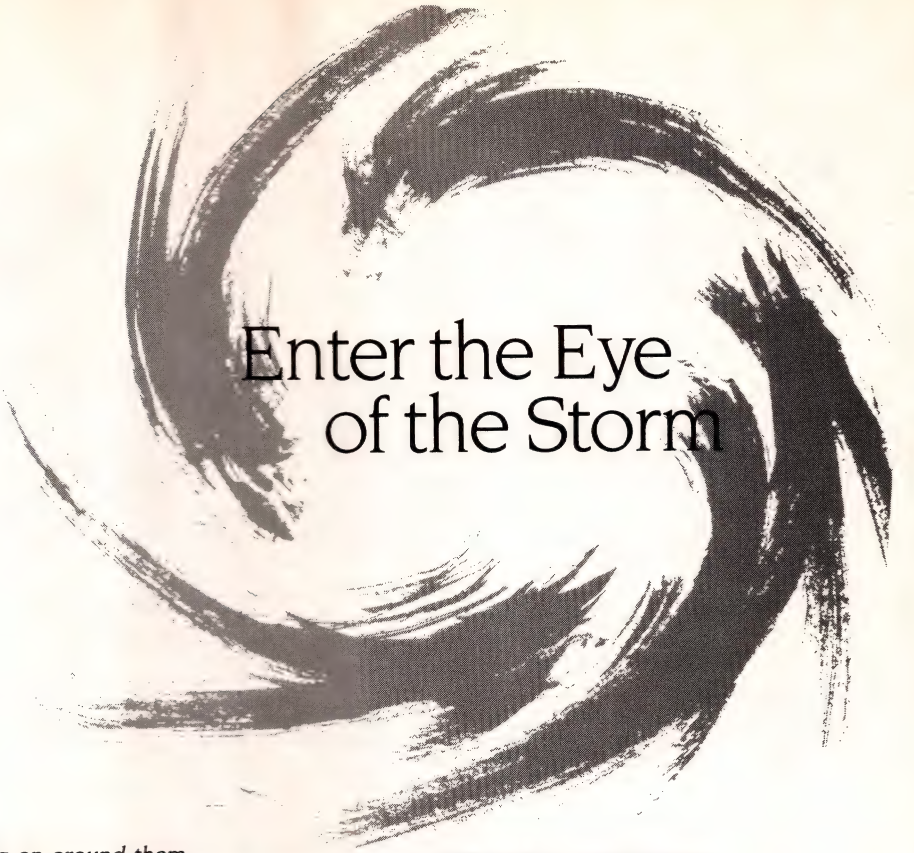

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EDITED BY CYNTHIA B RETTIG

Wider opportunities seen in European F-O market

A number of recent changes have brought European fiber-optic suppliers and consumers into the international marketing arena, according to Kessler Marketing Intelligence of Newport, RI. These changes include the doubling of the amount of fiber installed over long-haul networks by the postal, telephone, and telegraph companies; the liberalization of policies that govern competitive manufacturing and marketing; and the founding of several international R&D organizations. The European fiber-optic market is expected to grow steadily in the next five years, averaging an annual growth rate of 15% and reaching $1.9 billion in sales in 1993.

Telephony is and will remain the largest area of application as fiber invades feeder routes and subscriber loops. But the fastest growing application area will be data communications, which should grow at an average annual rate of 33%. Expected to decline in use and market share are long-haul installations, which reached a peak consumption of 317,000 km in 1987. On the other hand, video communications and military applications will account for significant shares of the market (although percentages vary notably from country to country).

Of the 15 countries it analyzed, KMI found that various factors, including fiber-optic installation plans, government limitations, and political motivations, characterize different corners of the market. The market in the United Kingdom is so competitive, for example, that the prices of many fiber-optic products in that country are half of what they are in West Germany.

Opportunities for foreign companies also vary from country to country. Some countries, like Italy, have policies that protect domestic manufacturing; partnerships and technology licensing, however, still leave doors open for foreign manufacturers. Other countries, like the UK, have instituted policies that encourage foreign suppliers. Consequently, several overseas countries compete in the British fiber-optic marketplace through alliances and distributors. In spite of these opportunities, KMI points out, it's important to remember that almost every country has at least one strong domestic manufacturer.

Switching power supplies will grow at 14% annual rate

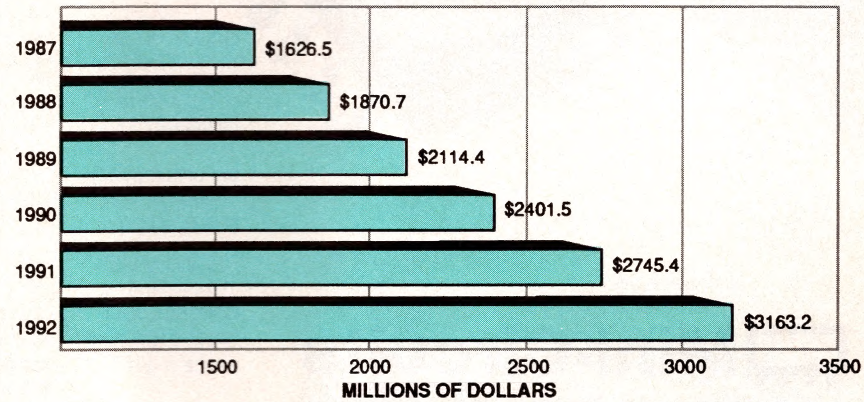
The annual growth rate for sales of ac/dc and dc/dc switching power supplies should average 14% through 1992, market researchers at Venture Development Corp (Natick, MA) have found. The market share for ac/dc supplies will continue to dominate the total market, but dc/dc unit shipments will grow faster and so gain some market share during the forecast period.

VDC found that the US market for ac/dc and dc/dc power supplies is highly fragmented. In fact, any one of the big suppliers accounts for less than 6% of the total shipments for 1987. The market-research company anticipates some consolidation of vendors in the next few years through mergers, acquisitions, and business failures.

Custom products largely define the US merchant market. Although many manufacturers offer standard products, most frequently these devices are standards to the individual company and not to the industry at large. Offshore production accounts for a significant percentage of shipments for both ac/dc and dc/dc switching power supplies in the US market, but actual import numbers are lower than one might expect because many US-based companies have offshore production facilities.

OEMs in the computer and peripheral areas will continue to dominate the US market for ac/dc switching power supplies during the next few years. Similarly, OEMs in the military/aerospace and communications areas will remain the major consumers of dc/dc switching power supplies; areas to watch involve computer and peripheral systems, and office automation and business systems because they, too, are rapidly developing a greater reliance on these dc/dc devices.

TOTAL SHIPMENTS OF AC/DC AND DC/DC SWITCHING POWER SUPPLIES



(SOURCE: VENTURE DEVELOPMENT CORP)

tiny SPDT switches

absorptive... reflective

dc to 4.6GHz from $32.95 (1-24)

Tough enough to pass stringent MIL-STD-883 tests, useable from dc to 6GHz and smaller than most RF switches, Mini-Circuits' hermetically-sealed (reflective) KSW-2-46 and (absorptive) KSWA-2-46 offer a new, unexplored horizon of applications. Unlike pin diode switches that become ineffective below 1MHz, these GaAs switches can operate down to dc with control voltage as low as -5V, at a blinding 2ns switching speed.

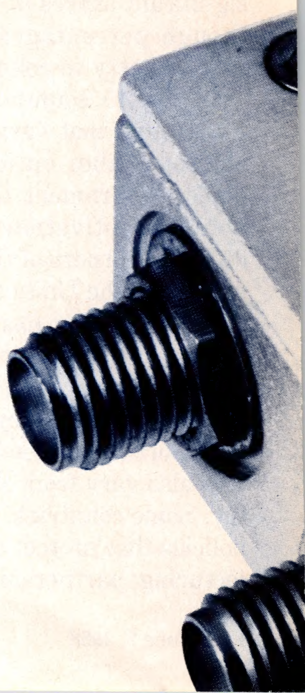
Despite its extremely tiny size, only 0.185 by 0.185 by 0.06 in., these switches provide 50dB isolation (considerably higher than many larger units) and insertion loss of only 1dB. The absorptive model KSWA-2-46 exhibits a typical VSWR of 1.5 in its "OFF" state over the entire frequency range. These surface-mount units can be soldered to pc boards using conventional assembly techniques. The KSW-2-46, priced at only $32.95, and the KSWA-2-46, at $48.95, are the latest examples of components from Mini-Circuits with unbeatable price/performance.

Connector versions, packaged in a 1.25 x 1.25 x 0.75 in. metal case, contain five SMA connectors, including one at each control port to maintain 3ns switching speed.

Switch fast... to Mini-Circuits' GaAs switches.

SPECIFICATIONS

Pin Model	KSW-2-46		KSWA-2-46	
Connector Version	ZFSW-2-46		ZFSWA-2-46	
FREQ. RANGE	dc-4.6 GHz		dc-4.6 GHz	
INSERT. LOSS (db)	typ	max	typ	max
dc-200MHz	0.9	1.1	0.8	1.1
200-1000MHz	1.0	1.3	0.9	1.3
1-4.6GHz	1.3	1.7	1.5	2.6
ISOLATION (dB)	typ	min	typ	min
dc-200MHz	60	50	60	50
200-1000MHz	45	40	50	40
1-4.6GHz	30	23	30	25
VSWR (typ) ON	1.3:1		1.3	
OFF	—		1.4	
SW. SPEED (nsec) rise or fall time	2(typ)		3(typ)	
MAX RF INPUT (bBm)				
up to 500MHz	+17		+17	
above 500MHz	+27		+27	
CONTROL VOLT.	−5V on, OV off		−5V on, OV off	
OPER/STOR TEMP.	-55° to +125°C		-55° to +125°C	
PRICE (1-24)	**$32.95**		**$48.95**	
	$72.95		**$88.95**	



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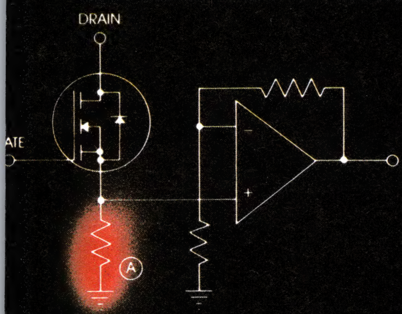
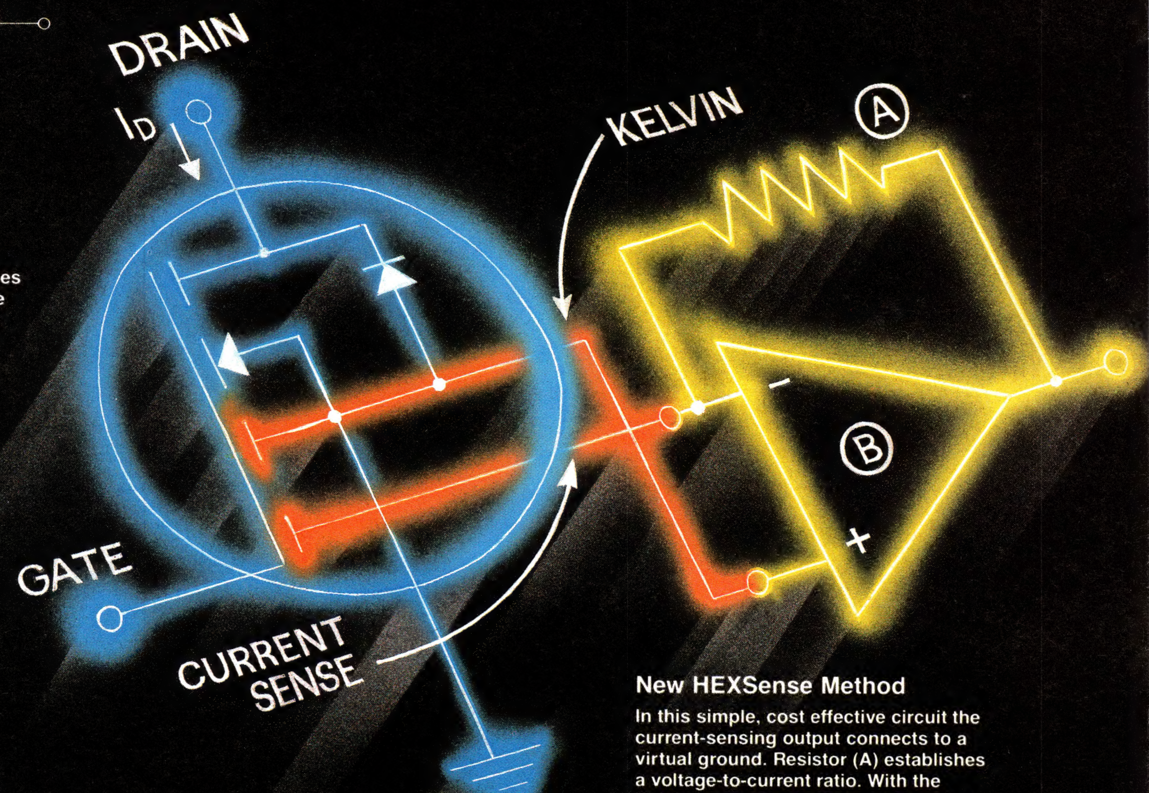


Old Method

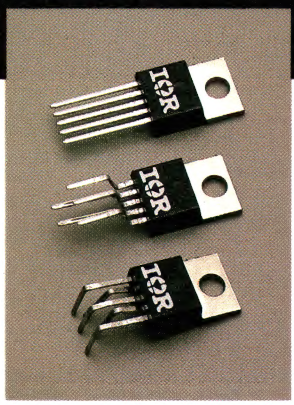
This circuit uses a fractional value resistor (A) to measure current, causing a voltage drop which increases power losses. Its parasitic inductance also slows down switching speed. To offset these losses, a lower $R_{DS(ON)}$ power MOSFET may be used, increasing circuit cost.



New HEXSense Method

In this simple, cost effective circuit the current-sensing output connects to a virtual ground. Resistor (A) establishes a voltage-to-current ratio. With the Kelvin connected to the non-inverting input of (B), a highly accurate current-sense results.

HEXSense offers 5-pin lead forms for vertical and horizontal pcb mounting.



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It's all made possible by our HEXFET power MOSFET's superior quality, faster switching speed, built-in avalanche withstand capability, and now, current-sensing for control and protection.

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